Thermal Plume Studies in the vicinity of Calvert Cliffs Nuclear Power Plant 1977 - 1978

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INTRODUCTION

Objectives of Study

Between August 1977 and August 1978, at the request of the State of Maryland Power Plant Siting Program, the Academy of Natural Sciences of Philadelphia conducted four hydrothermal studies on the Chesapeake Bay in the vicinity of the Calvert Cliffs Nuclear Power Plant under Contract No. P9-73-02. The studies were designed to determine the distribution of temperature in the vicinity of the power plant, to estimate ambient temperature there, and to estimate the configuration and extent of the Calvert Cliffs Nuclear Power Plant thermal plume under various hydrographic, plant operating and meteorologic conditions.

Plant Description

The Calvert Cliffs Nuclear Power Plant is located on the western shore of the Chesapeake Bay approximately 15 km north of its confluence with the Patuxent River. The plant has two nuclear units which typically generate between 1600 and 1800 megawatts of electric power (MWe) at full operation. It has a once-through cooling system which draws Chesapeake Bay water at a rate of 5500 cfs from below a curtain wall at the plant intake. The curtain wall forms an enclosed embayment and extends to a depth of 9 m. A 15-m deep intake channel extends from the curtain wall perpendicular to the shore line for a distance of approximately 1300 m. At full plant capacity the cooling water is heated between 5 and 6°C. It is discharged at a velocity of 3 m/sec from four rectangular pipes which terminate 500 m northeast of the plant intake.

Objectives of Report

This report has a two-fold purpose. The first is to present the results from the fourth, and final, hydrothermal study, conducted in August 1978. The results of the first three studies were previously reported in three technical reports which appear as Appendices A, B and C of this report. The second is to present conclusions drawn from an interpretive analysis of the estimated dimensions of the thermal plume under various hydrographic, plant operating, and meteorologic conditions. Included is a comparison of plume dimensions from these studies, conducted with two generating units operating, with those from studies done for the State of Maryland by Martin Marietta Laboratories in 1975 and 1976 (Martin Marietta Corporation, 1976a,b) when one generating unit was operating.

METHODS AND EQUIPMENT

Hydrothermal Studies

Four hydrothermal studies were conducted: Study 1 on August 18-19, 1977, Study 2 on November 1-3, 1977, Study 3 on April 20, 1978 and May 12-13, 1978, and Study 4 on August 22-23, 1978. Each study consisted of four surveys scheduled to coincide with the predicted times of slack before ebb, maximum ebb, slack before flood, and maximum flood tides. Each survey included mapping of the thermal plume, collection of temperature data along a lateral transect and a longitudinal transect near Kenwood Beach to estimate ambient water temperatures and the vertical profiling of hydrographic variables at three stations. Field methods and equipment, were basically the same for all studies except for the depths at which temperatures were measured along the transects and during the mapping. In Study 1, temperatures were measured at 1, 3, 5, 7 and 9 m; in Study 2, at 0.5, 1, 3, 5 and 7 m; in Studies 3 and 4, at 0, 0.5, 1, 3, 5 and 7 m. Data reduction techniques were also basically the same for all studies. The following descriptions of plume mapping, ambient temperature measurements, vertical profiling, and data reduction are specifically for Study 4. The important differences in methods for Study 4 and for the other studies are noted.

Plume Mapping

Six YSI 15606 thermistors were used to measure temperature. Three were attached to the boat, approximately 0, 0.5, and 1 m below the surface. The other three thermistors were bound to a stress cable stabilized by a 2-ft ENDECO V-fin and towed at depths of 3, 5 and 7 m. An ENDECO depth probe was used to monitor the depth of the deepest thermistor. The desired towing angle was maintained by regulating boat velocity.

Analog signals from the six thermistors were converted into 0 to 100 mv signals proportional to temperatures from 0 to 50°C by a YSI signal conditioner. The conditioned signal was digitized and stored on magnetic cassette by a NERA Model 4 data logger. A record of the six thermistor readings was written to cassette tape by a manually operated switch on the NERA data logger. Temperature data acquired by this system are accurate to within 0.2°C. The thermistors were calibrated before and after the study against an ASTM standard thermometer which was checked against the NBS standard thermometer used by Baltimore Gas and Electric (BG&E) for calibrating plant thermistors.

During mapping, boat speed ranged between 5 and 10 km/h. A temperature meter built into the YSI signal conditioner continuously displayed the temperature reading of any given thermistor. The observed temperature data were used in determining boat course. Each mapping lasted approximately 2 h during which temperature data were collected at 200 to 250 locations.

Two theodolites, stationed on shore, were used to determine boat position. The theodolites measure horizontal angles from a chosen zero to the nearest 10 sec. During a mapping, the theodolites were zeroed on one another. Each time a temperature record was written to cassette tape, the theodolite operators were signaled by two-way radio. Each operator immediately recorded the horizontal angle formed by the zero siting and the boat siting. These angles and theodolite location information were sufficient to determine the boat position accurate to within 5 m throughout the plume mapping area.

Ambient Temperature Measurements

To estimate ambient water temperature, temperatures were measured along Transects 1 and 2 (Fig. 1) immediately before each mapping using the methods described for plume mappings. Temperature data at up to six depths were recorded on cassette tape once every 15 sec while the boat maintained a constant velocity along each transect moving in the direction indicated by the arrow on each transect in Figure 1. Approximately 60 locations were sampled on Transect 1 and 40 locations on Transect 2.

Vertical Profiling

Vertical profiles of temperature, conductivity, dissolved oxygen and current velocity were made by sampling at 2-m depth intervals from the surface to the bottom at Stations A, B and C (Fig. 1). Data from Station A, in the middle of Transect 1, were used as measures of ambient hydrographic conditions. Data from Stations B and C were measures of hydrographic conditions near the discharge and intake of the plant, respectively. Profiles were determined at Station A at the time Transect 1 and 2 data were collected and at Stations B and C before and after each mapping. Temperature, conductivity and dissolved oxygen were measured with a Hydrolab Environmental Monitor. A Marsh-McBirney Model 727 current meter was used to measure current velocity. Salinity (°/₀₀) and density (expressed as Sigma T, or $\sigma_T = (\rho - 1.00) \times 10^3$*) were calculated from observed temperature and conductivity data. Current velocities were resolved into a longitudinal component, u (cm/sec), along

* ρ = density of water in g/ml as calculated from salinity and temperature.

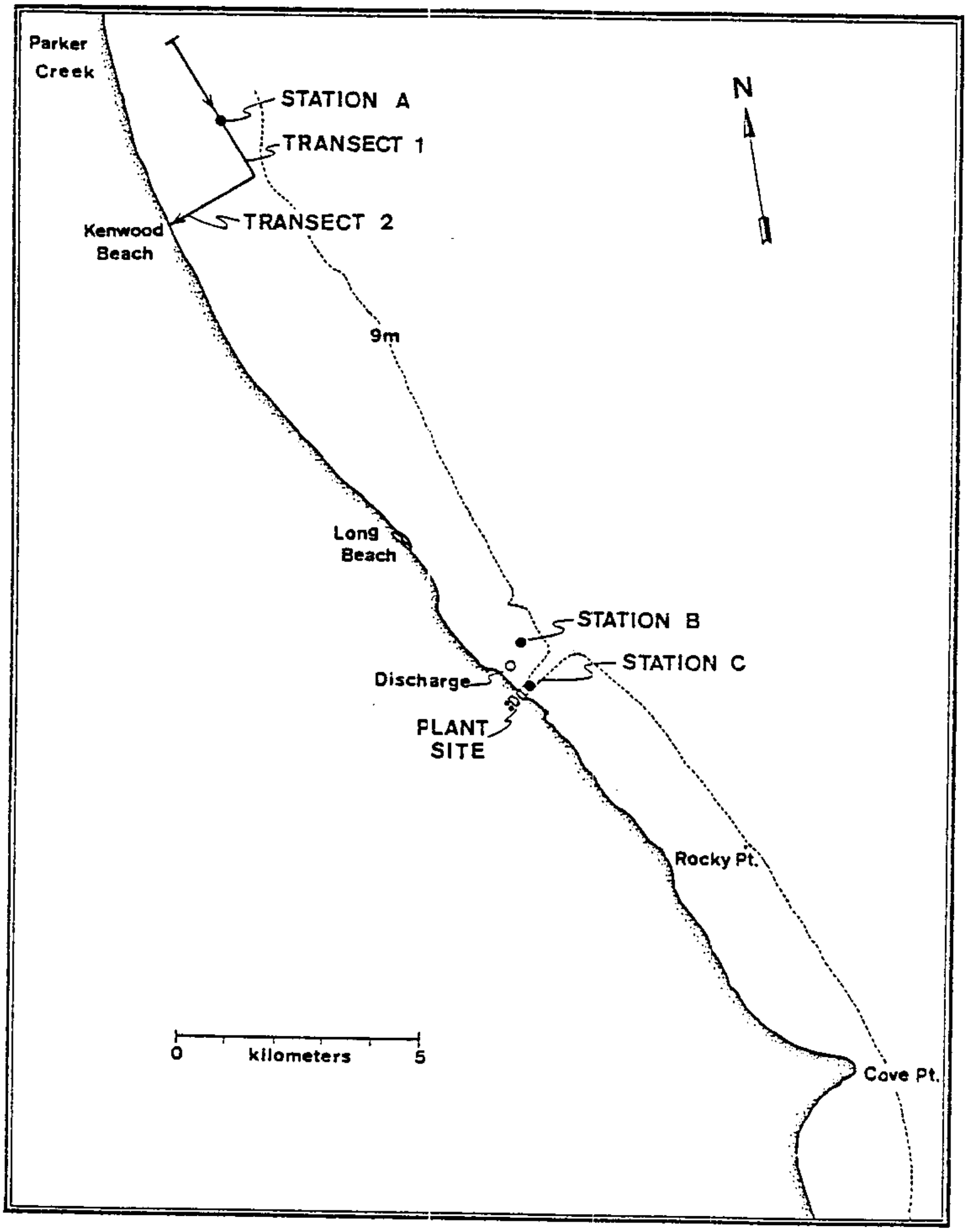

Figure 1. Location of thermal plume studies in the vicinity of Calvert Cliffs Nuclear Power Plant.

the tidal direction of 160-340^{o} true (positive upestuary) and a lateral component, v (cm/sec), perpendicular to the tidal direction (positive toward the eastern shore).

Data Reduction

Temperature data stored on cassette tape during the surveys were listed on a low-speed computer terminal. These data and the manually-recorded theodolite data were then stored on computer cards. All temperature data collected at a given depth during a plume mapping were mapped on a Calcomp electromagnetic plotter. Each temperature value at a given depth was plotted at the map location corresponding to the position of the boat when that measurement was taken.

Ambient temperatures for each depth were estimated from data collected along Transects 1 and 2 near Kenwood Beach. In order to reflect the variability in temperature along the transects at a given depth, a range of estimates of ambient temperature was chosen for each depth. The limits of each range were the 5th and 95th percentiles of the transect data of that depth. As a mean estimate of ambient temperature at each depth, the mean of the transect temperatures was chosen. This method of estimating ambient temperatures was also used in Study 3, during which temperatures along the transects were highly variable. In Studies 1 and 2, ranges of estimates of ambient temperature were not calculated because of the low variability in transect temperatures. In these studies, the mean of the transect temperatures generally was used as the estimate at each depth. When trends in the transect data suggested a plant effect, ambient temperature was estimated using the mean of a subset of observations which appeared to be unaffected by the plant.

Excess temperature isotherms were hand-drawn on each plume map at 1°C intervals, using the mean estimates of ambient temperature. Contour locations were determined by linearly interpolating between observed temperatures. Isotherms were drawn to include as many non-isolated data points with temperatures greater than or equal to the designated excess value as possible. When the observed data were insufficient to close an isotherm using linear interpolation, the isotherm was closed by a dotted line at the limit of the data.

The areas enclosed by the excess temperature isotherms were measured with a Keuffel and Esser compensating polar planimeter. Maximum radial extents, measured from the point of discharge, were determined for isotherms contiguous to the discharge. Areas of isotherms closed with dotted lines and maximum radial extents measured to dotted lines are preceded by ">" in tables and represent estimated lower limits of plume dimensions.

Interpretive Analysis

The data from the four hydrothermal studies were summarized and analyzed semi-quantitatively for interrelationships among variables. The techniques employed were contingency table analysis, partial correlation analysis, regression analysis, and analysis using area-temperature relationships of general plume theory. Data from plume studies conducted by Martin Marietta Corporation (1976a,b) were used to compare plume dimensions with one (MML) and two (ANSP) generating units in operation. The techniques for the comparison were those used for the analysis for the ANSP data.

For each of the 16 plume mappings conducted by ANSP, maximum plume areas and maximum radial extents for the 2°C and 1°C isotherms, with their corresponding depths and ambient temperatures, were tabulated with meteorologic, hydrographic and plant operating conditions. Specifically, the meteorological conditions were the wind velocities parallel and perpendicular to the tidal axis of 160-340° true. Hydrographic conditions were the tidal phase predicted to occur at the time of the mapping, the current velocities parallel and perpendicular to the tidal axis, the salinities in the intake channel at the surface, 8 m, and bottom, the depth of the pycnocline at the intake, and the bottom-to-surface salinity difference at the reference station (Station A). The plant operating conditions were temperature of the water at the intake, cross-condenser temperature rise, and plant load. Variables with different definitions in the four studies were redefined and values were recalculated according to the common definition. Martin Marietta Laboratories supplied a similar data set from their plume studies (Dr. William Richkus, MML, personal communication). Plant-operating records were supplied by Baltimore Gas and Electric Company (N. G. Lassahn, BG&E, personal communication).

A frequency distribution was determined for each variable in the ANSP data set. The range of values for a given variable was divided into five intervals of equal lengths. The number of observations falling into each interval indicated how the data were distributed across the range.

Contingency analysis was used to test for independence between pairs of variables. This analysis uses rxc tables (r groupings or categories of one variable and c groupings of the other variable) with (r-1) (c-1) degress of freedom (*d.f.*). The test for independence compares the observed cell frequencies with cell frequencies expected from probability theory if the variables were independent. The test statistic, χ^2, has a chi-square probability distribution. If the computed χ^2 is greater than the tabulated χ^2 at a level α and with *d.f.* of $(r-1)(c-1)$, then the test has a significance of $(100-\alpha)\%$ and the null hypothesis of independence between the variables is rejected. For a more in-depth discussion of the analysis of contingency tables, see Everitt (1977).

Most variables were tested using a 2 x 2 contingency table. Unless a given variable was naturally divided into distinct categories (e.g., tidal phase) or the data were grouped in one portion of the range, the data for each variable were grouped into categories defined by the midpoint of the range. When the data were grouped in one portion of the range, the categories were chosen so that the number of observations in each category was approximately equal.

This analysis was used to identify associations qualitatively. Significance levels of the chi-square test were treated as guidelines for interpreting the strength of associations seen in the data, not as strict cut-off points for independence versus dependence.

Partial correlation analysis was run on pairs of ungrouped data to determine if any quantitative relationships could be observed in the data set. Correlation coefficients close to 1.00 indicated that variables were highly correlated. Least squares regression analysis was used to fit functional relationships between highly correlated variables.

An empirical area-temperature analysis of the plume, based on the general plume theory presented in Chapter 5 of Edinger et al. (1974), was applied to the ANSP data and to the joint ANSP/MML data set. In this analysis, the maximum area of an excess temperature isotherm was used as the major parameter in the comparison of reduced field data to plume theories. Area-temperature equations derived from the theoretical jet plume relationships are generally power laws with significant processes grouped as scaling parameters. The field data were fit to the following empirical area-temperature relationship:

$$\text{Area/Plant Load} = a(\theta/\theta_0)^b(1-\theta/\theta_0)$$

where Area = surface area of an excess temperature isotherm ($\times 10^4$ m^2)
Plant Load is expressed in MWe
θ = excess temperature above ambient temperature (°C)
θ_0 = cross-condenser temperature rise from ambient temperature
and a,b = dimensionless parameters.

In this way, it could be determined whether the field data were consistent with plume theory.

RESULTS AND DISCUSSION

Hydrothermal Study 4

Survey 4A

Survey 4A was conducted on August 22, 1978 between 0845 and 1153 hours. Maximum ebb tidal velocity was predicted to occur at 1052 hours. During the survey, air temperature and wind velocity, measured at Calvert Cliffs by BG&E, averaged 22°C and 2.0 m/sec from the north, respectively (N.G. Lassahn, BG&E, personal communication). Mean plant load over the survey was 1487 MWe: mean cross-condenser temperature rise was 5.3°C. Plant operating, hydrographic and meteorologic conditions are summarized for the plume mapping portion of each survey in Table 1.

Vertical profiles of hydrographic variables at Station A (measured before Mapping 4A) and at Stations B and C (measured before and after Mapping 4A) are presented in Tables 2-6. Salinities ranged between 9.8 and 16.1°/₀₀. Stratification was weak at Stations A and B, with top-to-bottom differences of approximately 2°/₀₀. At Station C, in the intake channel, the top-to-bottom difference was 5.6°/₀₀, with the steepest gradient between the 8- and 10-m depths. Dissolved oxygen concentrations ranged from 0.1 to 8.3 ppm over the three stations. The lowest concentrations occurred at Station C between 10 and 14 m. On the average, the concentrations at Station C dropped 5.5 ppm between 8 and 10 m. The saturation level of dissolved oxygen in water at 27°C with a salinity of 10°/₀₀ is 7.5 ppm. In the upper layers, concentrations tended to be near saturation; however, below 6 m, they were below saturation. The component of current velocity along the tidal axis, averaged over depth before and after the mapping, was downestuary at 14.4 cm/sec at Station B, indicating that the tide was in the ebb stage.

Plume Mapping 4A was conducted between 1013 and 1137 hours, during which temperatures were measured at 0, 0.5, 1, 3, 5 and 7 m at 245 locations in the plant vicinity. The temperatures collected along Transects 1 and 2 before the mapping at Kenwood Beach (Fig. 1) are listed in Tables 7 and 8. A warming trend of 0.1°C was found at the end of Transect 1 nearest the plant. Temperatures decreased shoreward along Transect 2 by approximately 0.6°C. The range and the mean of ambient temperature estimates were derived from the transect data as described earlier in this report. The ranges were between 0.3 and 0.6°C. The mean estimates varied little with depth: all were between 26.7-26.8°C (Table 9). Using the mean estimates of ambient temperature, excess temperature isotherms were drawn on each map according to the techniques described earlier in this report. Table 9 summarizes by depth the ranges and means of the estimates of ambient temperature and the areas and maximum radial extents of the excess temperature isotherms. The isotherms are shown with the temperatures observed during the mapping for each depth in Figures 2-7.

Survey 4B

Survey 4B was conducted on August 22, 1978 between 1433 and 1744 hours. Maximum flood tidal velocities were predicted to occur at 1715 hours. Air temperature averaged 25.4°C, which was 3.4°C higher than during the morning survey. Wind velocity during Survey 4B averaged 2.3 m/sec from the northeast. Mean plant load and cross-condenser temperature rise for the survey were 1528 MWe and 5.2°C, respectively (N.G. Lassahn, BG&E, personal communication).

Vertical profiles of hydrographic variables measured at Stations A, B and C are presented in Tables 10-14. Salinity profiles were similar to those of the morning survey (Survey 4A). Salinities ranged over the three stations from 9.4 to 15.7°/₀₀. Stratification at Station A (representing ambient conditions) was low: the top-to-bottom difference was 1.0 °/₀₀. Stratification was highest at Station C in the intake channel, with an average top-to-bottom difference of 6.0°/₀₀. The strongest gradient occurred at depth, between 10 and 14 m. Dissolved oxygen concentrations ranged from 0.3 to 13.7 ppm, with low values only at depth at Station C. They were generally higher than in Survey 4A, probably because of increased photosynthetic activity in the afternoon (K. Heck, ANSP, personal communication). The component of current velocity along the tidal axis at Station B averaged over depth before and after the mapping was upestuary at 15.9 cm/sec, indicating that the tide was in the flood stage during the mapping.

Plume Mapping 4B was conducted between 1603 and 1727 hours, during which temperature profiles were taken at 245 locations in the plant vicinity. The temperatures measured before the mapping along Transects 1 and 2 are listed by depth in Tables 15 and 16. Solar heating resulted in a rise in ambient temperature in the upper layers of approximately 1.5°C from the morning survey. Temperatures below 1 m remained nearly the same. Mean estimates of ambient temperature ranged over depth from 26.8 to 28.5°C, with estimates in the top meter approximately 1 to 1.5°C higher than in the rest of the water column. At each depth the range of estimates was ≤ 0.5°C. The estimates of ambient temperature and the dimensions of the excess temperature isotherms drawn using the mean estimates of ambient temperature are listed by depth in Table 17. Maps showing the excess temperature isotherms with the temperatures observed during the mapping are presented for each depth in Figures 8-13.

Survey 4C

Survey 4C was conducted on August 23, 1978 between the hours of 0745 and 1103. Slack before ebb tide was predicted to occur at 0828. Over the survey period, the air temperature rose from 18.9°C at 0700 hours to 25.6°C at 1100 hours and averaged 22.0°C. Over the mapping period only, it averaged 23.7°C. Mean wind velocity for the survey was 2.4 m/sec from the southwest. Mean plant load for the survey was 1639 MWe and the cross-condenser temperature rise was 5.5°C (N.G. Lassahn, BG&E, personal communication).

The vertical profiles of hydrographic variables from Stations A, B and C are shown in Tables 18-22. Salinity profiles were very similar to those of Surveys 4A and 4B. Salinities ranged from 9.7 to 15.4°/₀₀. At Kenwood Beach (Station A), and at the discharge (Station B), stratification was low, with top-to-bottom differences of 1.0 °/₀₀ and 0.5 °/₀₀, respectively. At the intake (Station C), the top-to-bottom difference averaged 4.8°/₀₀, with the strongest salinity gradient between 8 and 12 m. Dissolved oxygen concentrations were similar to those of Survey 4A done on the previous morning. Concentrations ranged from 0.2 to 7.9 ppm. In general, the water at the surface was close to the saturation level of 7.2 ppm but became increasingly unsaturated with depth. The component of current parallel to the tidal axis averaged over depth before and after the mapping at Station B was downestuary at 2.9 cm/sec, indicating that during the mapping the tide was probably near the slack-before-ebb stage.

Plume mapping 4C was conducted between 0930 and 1048 hours. Temperatures were measured at 0, 1, 3, 5 and 7 m at 213 locations. Temperatures could not be measured at 0.5 m because of equipment malfunction. Temperatures observed before the mapping along Transects 1 and 2 near Kenwood Beach are listed by depth in Tables 23 and 24. No strong trends along their lengths were apparent. The estimates of ambient temperature showed little variability. At each depth, the range of estimates was ≤ 0.4°C; the mean estimates varied between 26.7 and 27.0°C. Table 25 summarizes the estimates of ambient temperature and the dimensions of the excess temperature isotherms based on the mean estimates of ambient temperature. Figures 14-18 show by depth the maps of the observed temperatures with the excess temperature isotherms for Mapping 4C.

Survey 4D

Survey 4D was conducted on August 23, 1978 between 1412 and 1725 hours. Slack-before-flood tide was predicted to occur at 1445 hours. During the survey, air temperature and wind velocity averaged 27.6°C and 2.2 m/sec from the east, respectively. Mean plant load for the survey was 1606 MWe; mean cross-condenser temperature rise was 5.5°C (N.G. Lassahn, BG&E, personal communication).

Vertical profiles of hydrographic variables from Stations A, B and C for Survey 4D are shown in Tables 26-30. Salinities ranged between 9.4 and 15.1 °/oo. Station A, near Kenwood Beach, showed slightly higher stratification than in the other three surveys, with a top-to-bottom difference of 2.5 °/oo. Top-to-bottom differences at Station C in the intake channel averaged 5.0 °/oo. The steepest gradient in salinity occurred between 12 and 14 m. The profile at Station B before the mapping showed no stratification in salinity or dissolved oxygen, probably because readings had been taken too close to the discharge jet. The other profiles showed top-to-bottom differences in dissolved oxygen concentrations of 6.3 to 11.8 ppm. As in Survey 4B (done on the previous afternoon), dissolved oxygen concentrations were higher than in the morning survey, Survey 4C, probably because of increased photosynthetic activity in the afternoon (K. Heck, ANSP, personal communication). Except for depths below 10 m, the concentrations were near the saturation level of about 7.5 ppm for water that is between 26 and 28°C with a salinity of 10 to 12 °/oo.

The current profiles at Station B before the mapping were affected by the discharge, so they are not good indicators of tidal stage. However, the fact that the longitudinal components of current velocity were downestuary at Station A an hour before the mapping and they were upestuary at Station B after the mapping indicated that the slack-before-flood stage occurred during the mapping. The component along the tidal axis at Station C averaged over depth before and after the mapping was 3 cm/sec upestuary.

Plume Mapping 4D was conducted between 1539 and 1711 hours, during which temperatures were measured at 0, 1, 3, 5 and 7 m at 250 locations. Data were not collected at 0.5 m because of equipment malfunction. The temperature data collected before the mapping along Transects 1 and 2 near Kenwood Beach are listed for Survey 4D in Tables 31 and 32. Solar heating considerably warmed the top meter compared to the morning survey. The mean estimates of ambient temperature at 0 and 1 m increased between Mapping 4C and 4D from 26.9 to 29.0°C and from 26.7° to 28.5°C, respectively. For Mapping 4D, the difference between mean estimates in the top meter and those below was on the order of 1.5-2°C. The ranges of estimates varied from 0.2 to 1.2°C with depth. The largest ranges occurred at 1 and 3 m, the layer that was marginally in the influence of solar heating. The estimates of ambient temperature and the dimensions of the excess temperature isotherms based on the mean estimates of ambient temperature are presented in Table 33. Figures 19-23 are maps showing the excess temperature isotherms with the temperatures observed during the mapping for each depth.

Summary of Results, Surveys 4A-4D

Meteorological and plant operating conditions for Mappings 4A, 4B, 4C and 4D are summarized in Table 1. Air temperatures during both morning mappings (4A and 4C) were similar, averaging 23.6°C. Air temperatures were much warmer in the afternoons. Between Mappings 4A and 4B, air temperature rose 2.4°C; between 4C and 4D, it rose 3.9°C. Average wind speeds ranged from 2.1 to 2.7 m/sec over the four mappings and their mean was 2.3 m/sec. Winds were generally from the north to east, except during Mapping 4C, when they were from the southwest. Average plant loads ranged from 1487 to 1644 MWe, their mean being 1575 MWe, or about 90% of full capacity. The average temperature rise of the intake water as it crossed the condensers was 5.4°C.

The patterns of salinity stratification were similar for all surveys. At Station A, near Kenwood Beach, salinities ranged over the four surveys from 9.5 to 12.0 ‰. Top-to-bottom differences were low: they ranged from 1.0 to 2.5 ‰ and averaged 1.6 ‰. Near the discharge, at Station B, stratification was lower than at Station A, probably because of mixing caused by the discharge jet. Top-to-bottom differences there averaged 0.6 ‰. Stratification in the intake channel (Station C) was higher than at the other stations, with top-to-bottom differences ranging from 4.5 to 6.1 ‰ and averaging 5.3 ‰. Stratification would be expected to be higher at the intake than at the other stations because the intake channel is approximately 5-10 m deeper than the adjacent, undredged areas and because the withdrawal of water by the plant induces a transport of deeper, more saline, water from offshore.

The temperatures along Transect 1 varied by approximately 0.2°C at each depth, except during Survey 4D, when they varied by $\geq$ 1°C at 1 and 3 m. Along Transect 2, temperatures were generally more variable and tended to be coolest near the shore. For each depth, the range of estimates of ambient temperature was defined as the 5th and 95th percentiles of the temperatures along Transects 1 and 2. Ranges varied over all the mappings and depths from 0.2 to 1.2°C and averaged 0.4°C. Widest ranges occurred in the two afternoon surveys, 4B and 4D, during which the temperatures above 1 m were rapidly changing from solar heating. Mean estimates of ambient temperature, defined for each mapping and depth as the mean of the temperatures along

Transects 1 and 2, ranged from 26.7 to 29.0°C. In the morning surveys, 4A and 4C, they varied little with depth; in the afternoon surveys, 4B and 4D, they varied 1.8 and 2.1°C over depth, respectively.

Table 1 lists for each mapping the maximum areas and the maximum radial extents of the 4, 3, 2 and 1°C isotherms drawn using the mean estimates of ambient temperature. The areas of the 4°C isotherms ranged over all mappings from 0 to 1×10^4 m^2 (2 acres) and averaged 0.5×10^4 m^2 (1 acre); the 3°C isotherms ranged from 0.8 to 5×10^4 m^2 (12 acres) and averaged 2×10^4 m^2 (5 acres). This set was the first of the four studies in which 3°C and 4°C excess temperature isotherms were found on this mapping scale at all depths for all mappings. The areas of the 2°C excess temperature isotherms ranged over all mappings from 2×10^4 m^2 (5 acres) to $>3 \times 10^5$ m^2 (74 acres) and averaged 1×10^5 m^2 (25 acres); the 1°C areas ranged from 7×10^4 m^2 (17 acres) to $>2 \times 10^6$ m^2 (494 acres) and averaged 1×10^6 m^2 (247 acres). Over all the mappings, the radial extents of the 4°C excess temperature isotherms, measured from the discharge on the plumes contiguous to the discharge, ranged from 0 to 0.3 km and averaged 0.1 km; for 3°C isotherms, they ranged from 0.2 to 0.8 km and averaged 0.3 km. The radial extents of the 2°C isotherms ranged from 0 to 2.2 km and averaged 0.8 km; those of the 1°C isotherms ranged from 0.7 to >2.8 km and averaged 1.7 km.

Throughout the study period, the depth at which the plume was largest was determined by only small changes in the salinity and temperature balance. However, in all four studies, plume dimensions did not vary widely throughout the water column.

Table 1. Summary of hydrographic and plant operating conditions and estimated areas and radial extents of excess temperature isotherms for the duration of thermal plume mappings at Calvert Cliffs Nuclear Power Plant, August 1978.

Mapping	4A	4B	4C	4D
Date	8/22	8/22	8/23	8/23
Time	1013-1137	1603-1727	0930-1048	1539-1711
Predicted tidal phase	Ebb	Flood	SBE	SBF
u (cm/sec)*	-14.4	15.9	-2.9	24.0
v (cm/sec)*	3.9	-3.6	9.7	4.0
Wind (m/sec)	2.7/N	2.1/NE	2.2/SW	2.4/E
Air temp. (°C)	23.5	25.9	23.7	27.6
Plant load (MWe)	1487	1540	1644	1628
Intake temp. (°C)	26.8	28.4	27.1	28.2
Cross-condenser temp. rise (°C)	5.3	5.2	5.5	5.5
Max. area enclosed by mean 4°C isotherm ($x10^4$ m^2)	0.5	0.8	1	1
Max. area enclosed by mean 3°C isotherm ($x10^4$ m^2)	2	5	3	5
Max. area enclosed by mean 2°C isotherm ($x10^4$ m^2)	10	>30	20	>30
Max. area enclosed by mean 1°C isotherm ($x10^4$ m^2)	>200	>100	>200	>100
Max. radial† extent of mean 4°C isotherm ($x10^3$ m)	0.1	0.2	0.3	0.3
Max. radial† extent of mean 3°C isotherm ($x10^3$ m)	0.3	0.8	0.5	0.6
Max. radial† extent of mean 2°C isotherm ($x10^3$ m)	0.8	2.2	1.2	2.0
Max. radial† extent of mean 1°C isotherm ($x10^3$ m)	1.4	>2.8	>1.5	2.1

* Mean longitudinal component of current velocity, u (positive upestuary), and mean lateral component, v (positive toward the eastern shore), derived from u and v measurements at Station B before and after the mappings.

† Measured from point of discharge.

Vertical profiles of hydrographic variables in the Chesapeake Bay near Calvert Cliffs, Maryland.

Table 2.

PROFILE: 4A1 DATE: 8/22/78

STATION: A TIME: 0845

Depth (m)	Temp (C)	Cond. (mmhos/cm)	Salinity ($^o/oo$)	Sigma T	D.O. (ppm)	Velocity (cm sec^{-1}/deg)	u (cm/sec)	v (cm/sec)
0*	26.7	17.2	9.8	4.0	6.8	3/0	3	1
2	26.7	17.2	9.8	4.0	6.8	7/3	7	2
4	26.7	17.2	9.8	4.0	6.8	7/-12	7	0
6	26.5	17.3	9.9	4.1	6.7	15/345	15	-1
8	26.3	20.1	11.7	5.5	4.0	18/315	15	-10
10	26.3	20.2	11.7	5.6	3.7	16/289	8	-13

Table 3.

PROFILE: 4A1 DATE: 8/22/78

STATION: B TIME: 0953

Depth (m)	Temp (C)	Cond. (mmhos/cm)	Salinity ($^o/oo$)	Sigma T	D.O. (ppm)	Velocity (cm sec^{-1}/deg)	u (cm/sec)	v (cm/sec)
0*	27.3	17.8	10.0	3.9	7.8	28/144	-25	11
2	27.4	17.9	10.0	4.0	7.0	21/165	-21	1
4	27.8	18.3	10.2	4.0	5.9	15/135	-13	8
6	27.5	20.1	11.3	4.9	3.8	18/95	-5	17
8	27.2	21.2	12.1	5.6	2.8	16/73	1	16

Table 4.

PROFILE: 4A2 DATE: 8/22/78

STATION: B TIME: 1148

Depth (m)	Temp (C)	Cond. (mmhos/cm)	Salinity ($^o/oo$)	Sigma T	D.O. (ppm)	Velocity (cm sec^{-1}/deg)	u (cm/sec)	v (cm/sec)
0*	27.1	17.7	10.0	4.0	8.3	28/173	-28	-3
2	27.1	17.8	10.1	4.1	6.3	25/183	-24	-6
4	27.7	18.2	10.2	4.0	6.0	21/185	-20	-6
6	27.4	18.4	10.3	4.2	5.7	13/204	-10	-7
8	27.5	18.5	10.4	4.2	5.6	7/73	1	7

* Surface current velocity readings were taken at 1-m depth to minimize surface-wave effects.

Vertical profiles of hydrographic variables in the Chesapeake Bay near Calvert Cliffs, Maryland.

Table 5.

PROFILE: 4A1 DATE: 8/22/78

STATION: C TIME: 1004

Depth (m)	Temp (C)	Cond. (mmhos/cm)	Salinity (°/oo)	Sigma T	D.O. (ppm)	Velocity (cm sec^{-1}/deg)	u (cm/sec)	v (cm/sec)
0*	27.8	18.1	10.1	3.9	6.2	6/135	-5	3
2	27.9	18.2	10.1	3.9	5.7	7/108	-3	6
4	28.0	18.3	10.2	3.9	5.9	13/130	-10	8
6	27.5	18.5	10.4	4.2	5.8	18/145	-17	7
8	27.1	19.0	10.8	4.6	4.9	7/203	-5	-4
10	25.6	24.8	14.9	8.1	0.2	6/280	2	-6
12	25.5	25.4	15.3	8.5	0.2	12/60	4	12
14	25.5	26.0	15.7	8.7	0.3	12/230	-6	-11

Table 6.

PROFILE: 4A2 DATE: 8/22/78

STATION: C TIME: 1153

Depth (m)	Temp (C)	Cond. (mmhos/cm)	Salinity (°/oo)	Sigma T	D.O. (ppm)	Velocity (cm sec^{-1}/deg)	u (cm/sec)	v (cm/sec)
0*	28.2	18.9	10.5	4.1	7.7	19/135	-16	10
2	28.1	18.8	10.4	4.1	7.6	19/129	-15	12
4	28.1	18.9	10.5	4.1	7.6	13/115	-8	10
6	28.0	19.0	10.6	4.2	7.2	11/131	-9	7
8	27.5	19.6	11.0	4.7	6.4	3/270	1	-3
10	25.7	25.2	15.1	8.3	0.1	19/251	-2	-18
12	25.5	25.8	15.5	8.6	0.1	13/221	-7	-10
14	25.7	26.6	16.1	9.0	0.2	10/58	3	9

* Surface current velocity readings were taken at 1-m depth to minimize surface-wave effects.

Table 7. Temperature data along Transect 1, Survey 4A, at six depths.

PROJECT: CALVERT CLIFFS TRANSECTS
MAPPING: 4A
DATE: 082278
TIMES: 0855 TO 0950

*** TRANSECT 1 TEMPERATURE (C) DATA ***

READING NO.	0 M	0.5 M	1 M	3 M	5 M	7 M
1	26.8	26.8	26.7	26.8	26.7	26.5
2	26.8	26.8	26.7	26.8	26.7	26.5
3	26.8	26.8	26.7	26.8	26.7	26.5
4	26.8	26.8	26.7	26.8	26.7	26.5
5	26.8	26.8	26.6	26.8	26.7	26.4
6	26.8	26.8	26.7	26.8	26.7	26.4
7	26.8	26.8	26.7	26.8	26.7	26.5
8	26.8	26.8	26.7	26.8	26.7	26.5
9	26.8	26.8	26.7	26.8	26.7	26.6
10	26.8	26.8	26.7	26.8	26.7	26.5
11	26.8	26.8	26.7	26.8	26.7	26.6
12	26.8	26.8	26.7	26.8	26.7	26.5
13	26.8	26.8	26.7	26.8	26.8	26.5
14	26.8	26.8	26.7	26.8	26.7	26.5
15	26.8	26.8	26.7	26.8	26.7	26.5
16	26.8	26.8	26.7	26.8	26.7	26.5
17	26.8	26.8	26.7	26.8	26.7	26.6
18	26.8	26.8	26.7	26.8	26.7	26.5
19	26.8	26.8	26.7	26.8	26.7	26.5
20	26.8	26.8	26.7	26.8	26.8	26.5
21	26.8	26.8	26.7	26.8	26.8	26.5
22	26.8	26.8	26.7	26.8	26.7	26.5
23	26.8	26.8	26.7	26.9	26.7	26.5
24	26.8	26.8	26.7	26.8	26.7	26.6
25	26.8	26.8	26.7	26.8	26.7	26.6
26	26.8	26.8	26.7	26.8	26.7	26.6
27	26.8	26.8	26.7	26.8	26.7	26.6
28	26.9	26.8	26.7	26.8	26.7	26.6
29	26.9	26.8	26.7	26.8	26.7	26.6
30	26.8	26.8	26.7	26.8	26.8	26.6
31	26.9	26.8	26.7	26.8	26.8	26.6
32	26.8	26.8	26.7	26.8	26.8	26.5
33	26.8	26.8	26.7	26.8	26.7	26.6
34	26.8	26.8	26.7	26.8	26.7	26.6
35	26.8	26.8	26.7	26.8	26.7	26.6
36	26.8	26.8	26.7	26.8	26.8	26.6
37	26.8	26.8	26.7	26.8	26.8	26.6
38	26.8	26.8	26.7	26.6	26.7	26.6
39	26.8	26.8	26.7	26.8	26.7	26.6
40	26.8	26.8	26.6	26.8	26.7	26.6
41	26.8	26.8	26.7	26.8	26.7	26.7
42	26.8	26.8	26.7	26.8	26.7	26.7
43	26.8	26.8	26.7	26.8	26.7	26.7
44	26.8	26.8	26.7	26.8	26.7	26.7
45	26.8	26.8	26.7	26.8	26.8	26.8
46	26.8	26.8	26.7	26.8	26.8	26.8
47	26.8	26.8	26.7	26.8	26.7	26.8
48	26.9	26.8	26.7	26.8	26.7	26.8
49	26.9	26.8	26.7	26.8	26.7	26.8
50	26.9	26.8	26.7	26.8	26.7	26.8
51	26.9	26.8	26.7	26.8	26.7	26.8
52	26.8	26.8	26.7	26.8	26.8	26.8
53	26.9	26.8	26.7	26.8	26.8	26.8
54	26.9	26.8	26.7	26.8	26.8	26.8
55	26.9	26.9	26.8	26.9	26.8	26.8
56	26.9	26.9	26.8	26.9	26.8	26.8
57	26.9	26.9	26.8	26.9	26.8	26.8
58	26.9	26.9	26.8	26.9	26.8	26.9
59	26.9	26.9	26.8	26.9	26.8	26.9
60	26.9	26.9	26.9	26.9	26.8	27.0

Table 8. Temperature data along Transect 2, Survey 4A, at six depths. Asterisks indicate data could not be collected.

PROJECT: CALVERT CLIFFS TRANSECTS
MAPPING: 4A
DATE: 082278
TIMES: 0855 TO 0950

*** TRANSECT 2 TEMPERATURE (C) DATA ***

READING NO.	0 M	0.5 M	1 M	3 M	5 M	7 M
1	26.9	26.9	26.8	26.9	26.8	25.9
2	26.9	26.9	26.8	26.9	26.6	26.8
3	26.9	26.9	26.8	26.9	26.8	26.8
4	26.9	26.9	26.8	25.9	26.8	26.8
5	26.9	26.8	26.8	26.9	26.8	26.8
6	26.9	26.8	26.8	26.9	26.8	26.8
7	26.9	26.8	26.8	26.8	26.8	26.8
8	26.9	26.8	26.8	26.8	26.7	26.8
9	26.9	26.9	26.8	26.9	26.8	26.8
10	26.9	26.9	26.8	26.9	26.8	26.8
11	27.0	26.9	26.8	26.9	26.8	26.8
12	27.0	26.9	26.8	26.9	26.8	26.8
13	27.0	26.9	26.8	26.9	26.8	26.8
14	27.0	26.9	26.8	26.9	26.8	26.8
15	27.0	26.9	26.8	26.9	26.8	26.8
16	27.0	26.9	26.8	26.9	26.8	26.8
17	27.0	26.9	26.8	26.9	26.8	26.8
18	26.9	26.9	26.8	26.9	26.8	26.8
19	26.9	26.8	26.8	26.8	26.8	26.8
20	26.9	26.8	26.7	26.8	26.8	26.8
21	26.9	26.8	26.7	26.7	26.8	*****
22	26.8	26.8	26.6	26.6	26.8	*****
23	26.8	26.8	26.6	26.7	26.8	*****
24	26.8	26.8	26.6	26.6	26.6	*****
25	26.8	26.7	26.5	26.5	26.6	*****
26	26.8	26.7	26.5	26.5	26.6	*****
27	26.8	26.6	26.5	26.5	26.6	*****
28	26.8	26.7	26.5	26.5	26.6	*****
29	26.8	26.6	26.5	26.5	26.5	*****
30	26.7	26.6	26.5	26.5	26.5	*****
31	26.7	26.6	26.5	26.5	26.5	*****
32	26.7	26.6	26.5	26.5	26.5	*****
33	26.6	26.6	26.4	26.4	26.5	*****
34	26.6	26.6	26.4	26.5	*****	*****
35	26.6	26.5	26.4	26.4	*****	*****
36	26.6	26.5	26.4	26.5	*****	*****
37	26.6	26.5	26.3	26.4	*****	*****
38	26.6	26.5	26.4	26.4	*****	*****
39	26.6	26.5	26.4	26.2	*****	*****
40	26.6	26.5	26.4	26.1	*****	*****
41	26.6	26.5	26.4	26.3	*****	*****
42	26.6	26.5	26.4	26.3	*****	*****
43	25.6	26.5	26.4	25.2	*****	*****
44	26.6	26.5	26.4	*****	*****	*****
45	26.6	26.5	26.3	*****	*****	*****
46	26.5	26.4	26.3	*****	*****	*****
47	25.3	26.3	26.0	*****	*****	*****
48	26.3	26.1	25.9	*****	*****	*****

Table 9. Estimated dimensions of excess temperature isotherms for Mapping 4A, Chesapeake Bay near Calvert Cliffs, Maryland.

Mapping:	4A	Wind (m/sec):	2.7/N
Date:	8/22/78	Air Temp. (°C):	23.5
Times:	1013-1137	Plant Load (MWe):	1487
Predicted Tidal Phase:	Ebb	Intake Temp. (°C):	26.8
u (cm/sec)*:	-14.4	Discharge Temp. (°C):	32.1
v (cm/sec)*:	3.9		

Depth (m)	Estimated Ambient Temp. (°C)		Excess Isotherm (°C)	Estimated Enclosed Area ($x10^4$ m^2)§	Estimated Maximum Radial† Extent ($x10^3$ m)§
	Range	Mean			
0.0	26.6-27.0	26.8	4	0.5	0.1
			3	2	0.3
			2	10	0.8
			1	>200	1.4
0.5	26.5-26.9	26.8	4	0.2	0.1
			3	2	0.3
			2	5	0.4
			1	>100	1.3
1.0	26.4-26.8	26.7	4	0.4	0.1
			3	2	0.3
			2	5	0.4
			1	>100	1.3
3.0	26.3-26.9	26.8	4	0.4	0.1
			3	2	0.3
			2	6	0.6
			1	>50	1.3
5.0	26.5-26.8	26.7	2	4	0.4
			1	>50	>1.3
7.0	26.5-26.9	26.7	2	3	0.6
			1	>70	1.3

* Mean longitudinal component of current velocity, u (positive upestuary), and mean lateral component, v (positive toward the eastern shore) derived from u and v measurements at Station B before and after the mappings.

§ Based on mean estimated ambient temperature.

† Measured from point of discharge.

Figures 2-7. Depictions of results of Mapping 4A at six depths in Chesapeake Bay near Calvert Cliffs, Maryland.

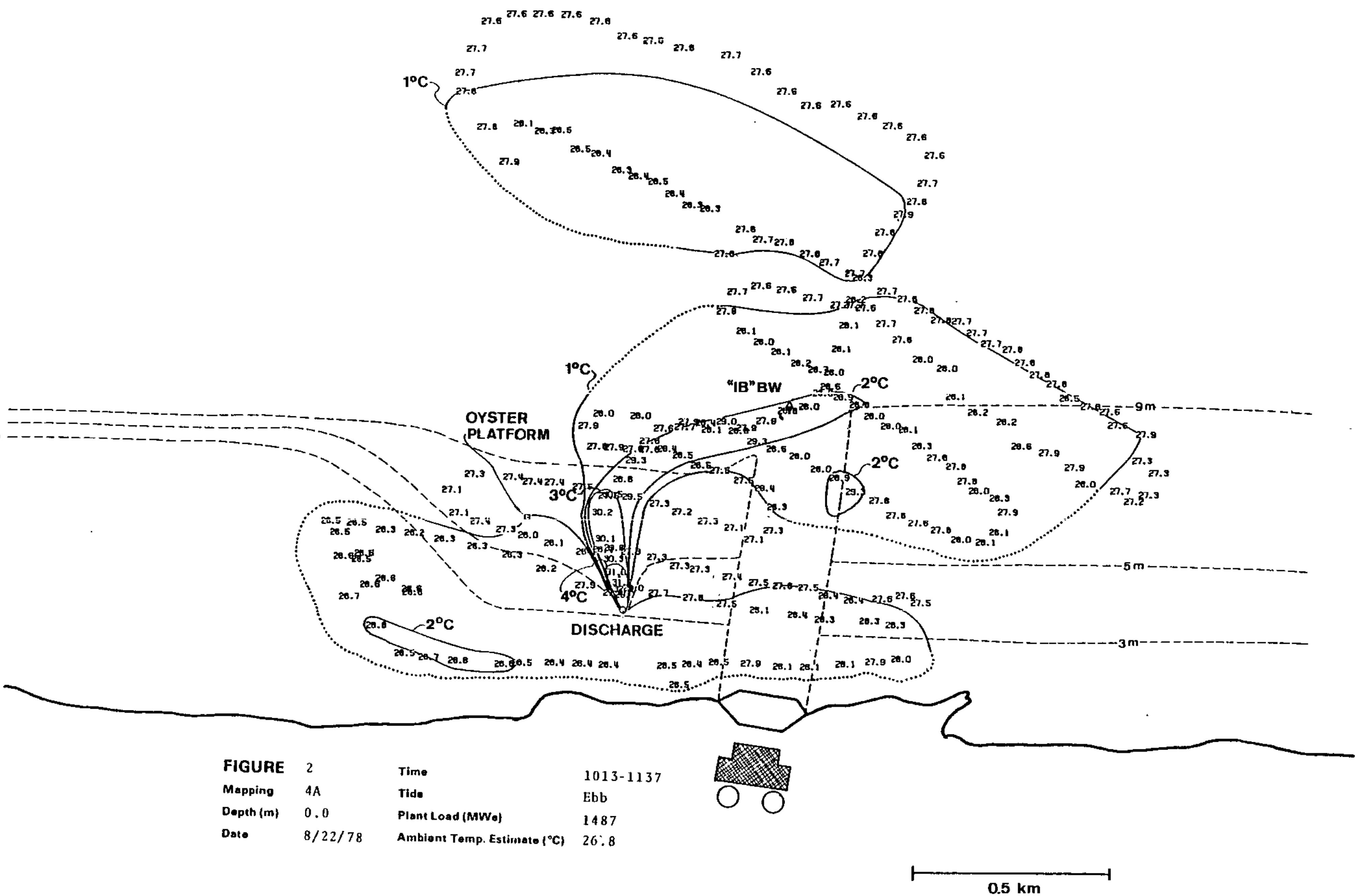

FIGURE	2	Time	1013-1137
Mapping	4A	Tide	Ebb
Depth (m)	0.0	Plant Load (MWe)	1487
Date	8/22/78	Ambient Temp. Estimate (°C)	26.8

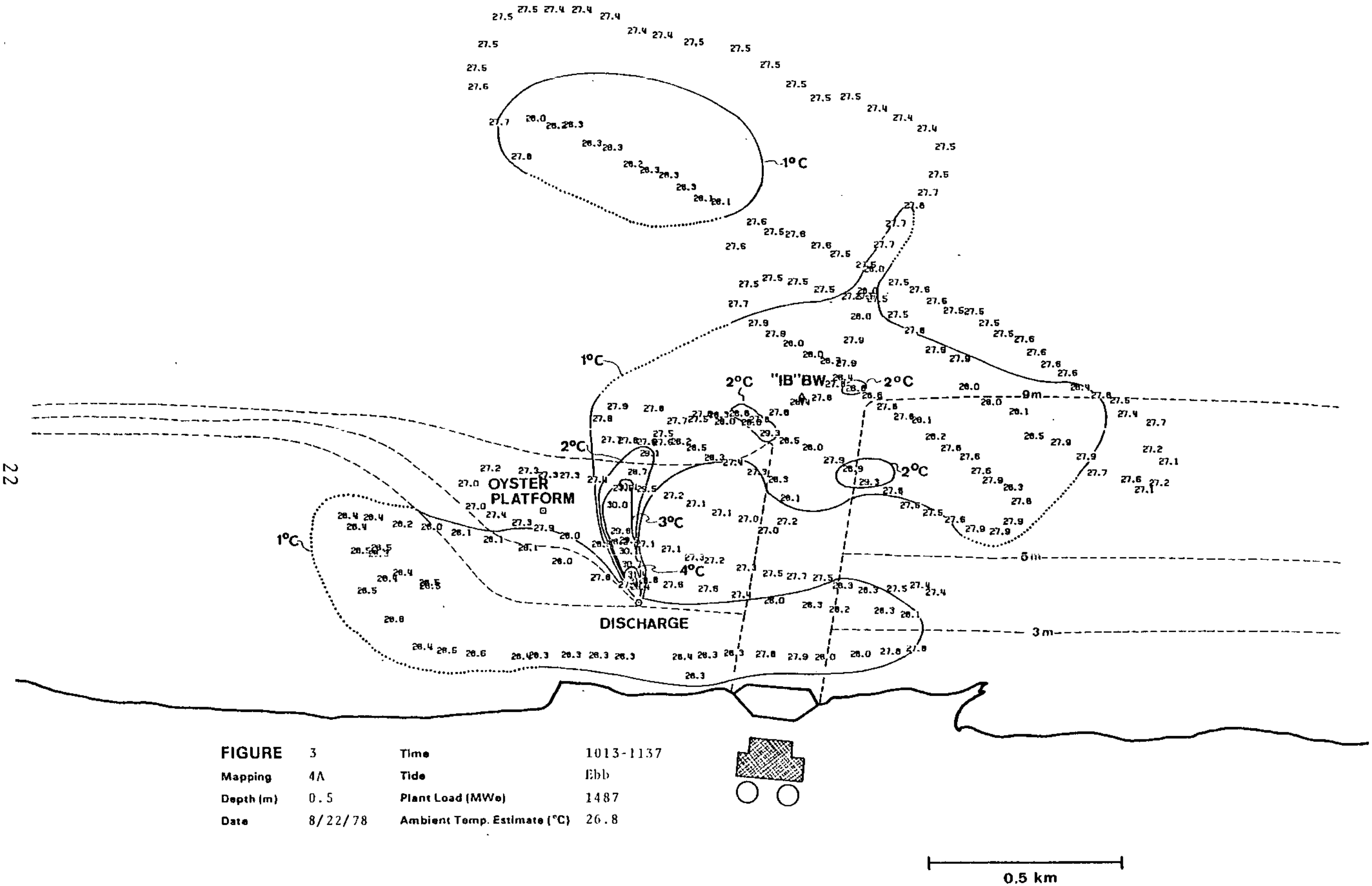

FIGURE	3	**Time**	1013-1137
Mapping	4A	**Tide**	Ebb
Depth (m)	0.5	**Plant Load (MWe)**	1487
Date	8/22/78	**Ambient Temp. Estimate (°C)**	26.8

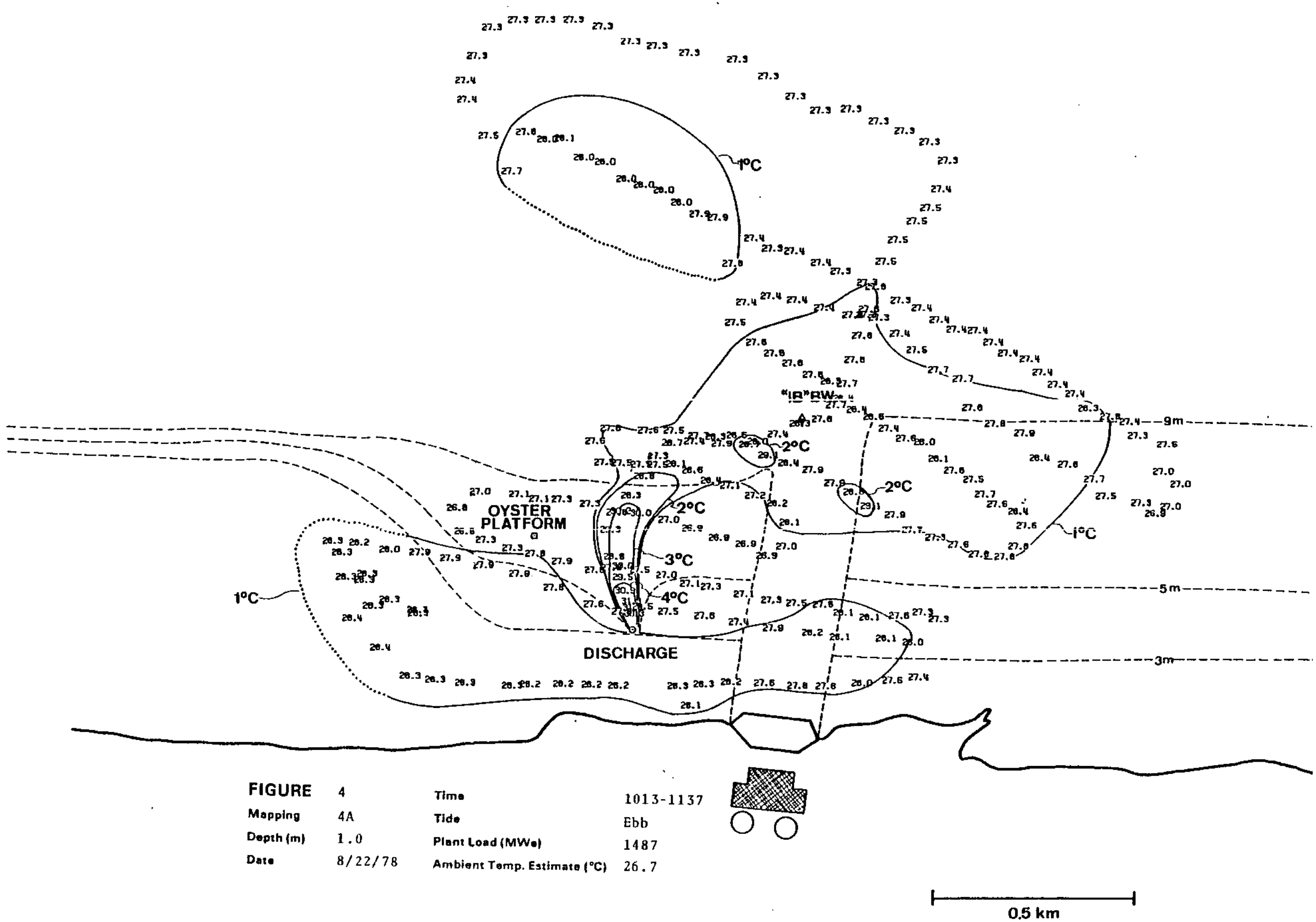

FIGURE 4
Mapping 4A
Depth (m) 1.0
Date 8/22/78
Time 1013-1137
Tide Ebb
Plant Load (MWe) 1487
Ambient Temp. Estimate (°C) 26.7

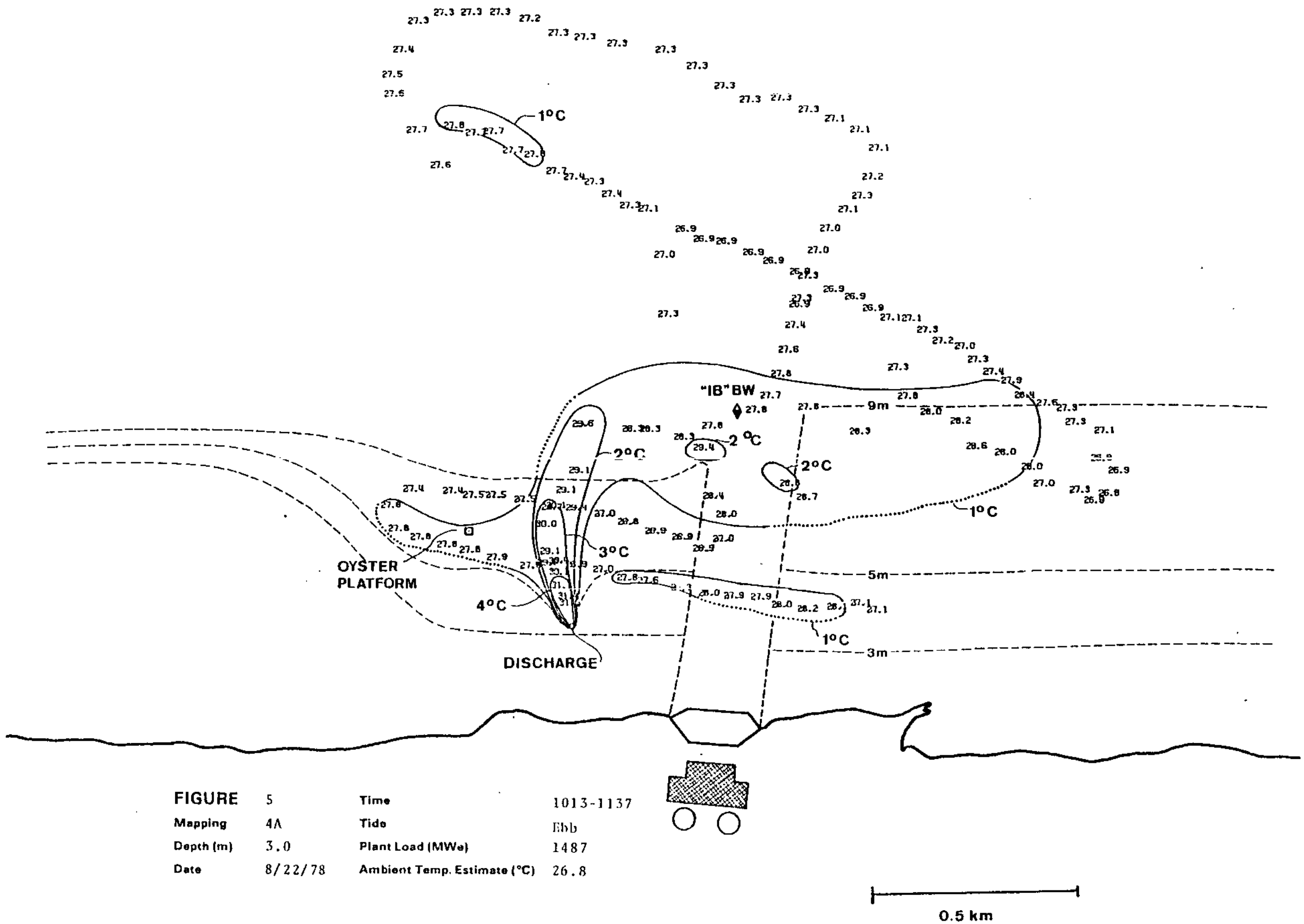

FIGURE	5	**Time**	1013-1137
Mapping	4A	**Tide**	Ebb
Depth (m)	3.0	**Plant Load (MWe)**	1487
Date	8/22/78	**Ambient Temp. Estimate (°C)**	26.8

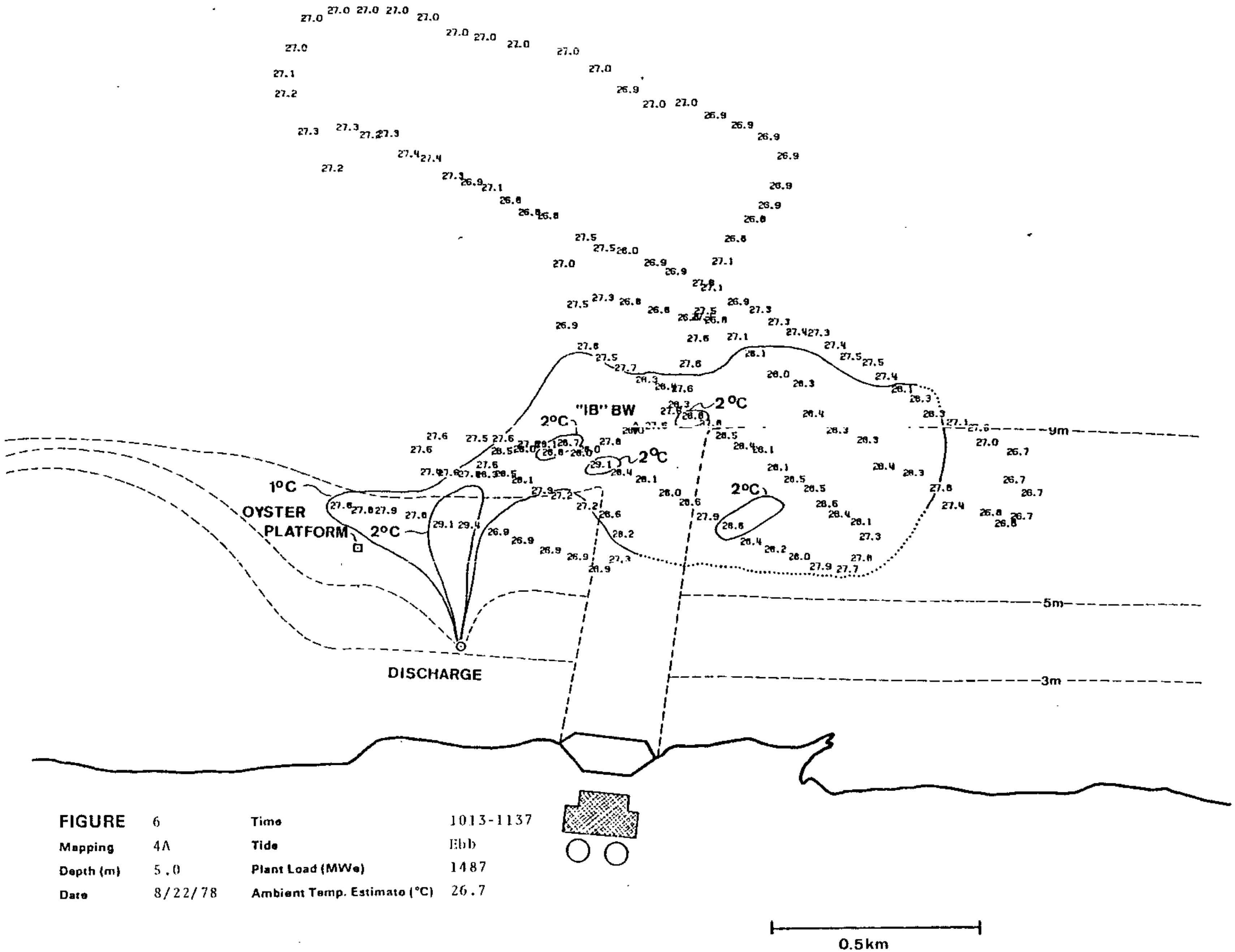

FIGURE	6	**Time**	1013-1137
Mapping	4A	**Tide**	Ebb
Depth (m)	5.0	**Plant Load (MWe)**	1487
Date	8/22/78	**Ambient Temp. Estimate (°C)**	26.7

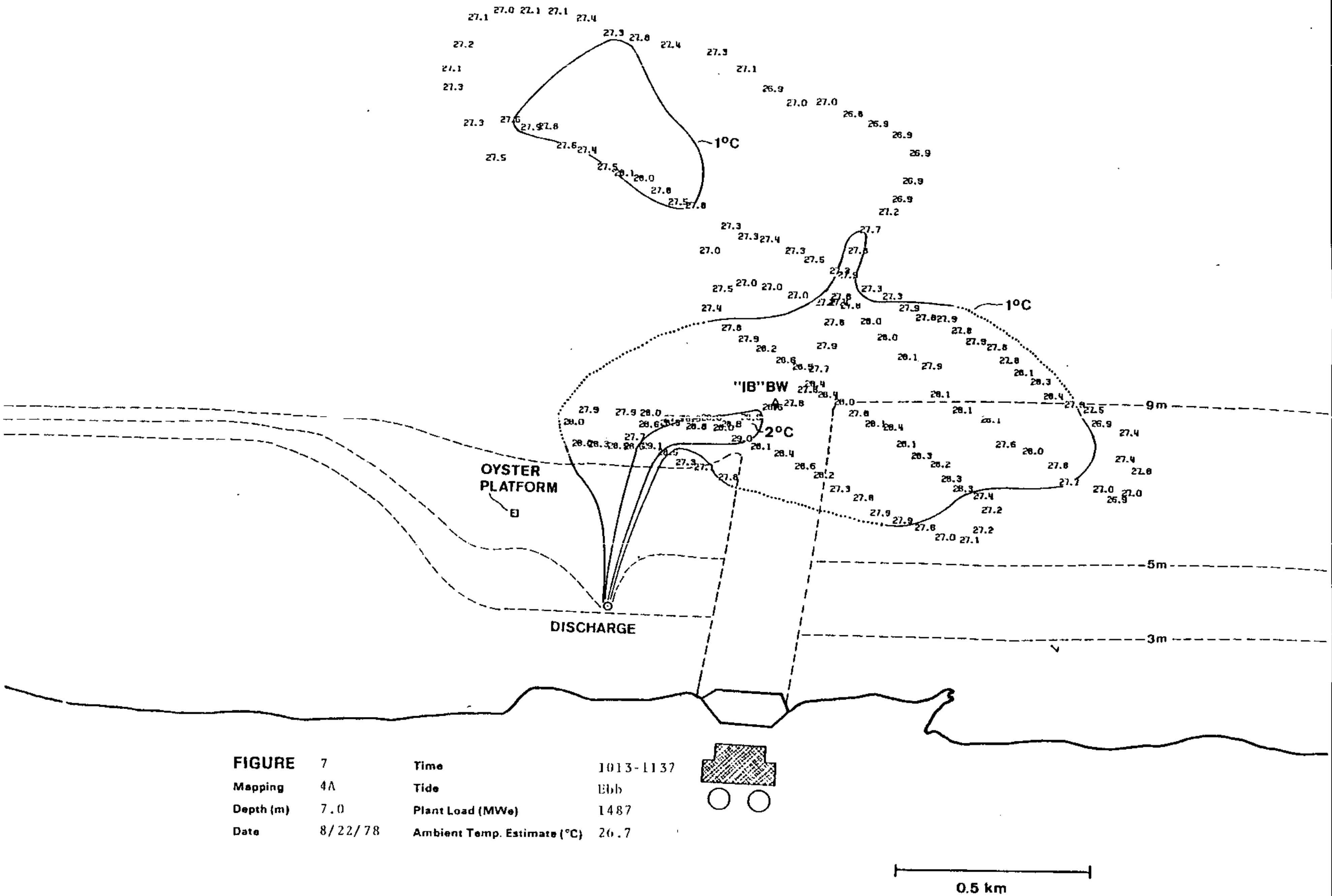

FIGURE 7
Mapping 4A
Depth (m) 7.0
Date 8/22/78
Time 1013-1137
Tide Ebb
Plant Load (MWe) 1487
Ambient Temp. Estimate (°C) 26.7

Vertical profiles of hydrographic variables in the Chesapeake Bay near Calvert Cliffs, Maryland.

Table 10.

PROFILE: 4B1 DATE: 8/22/78

STATION: A TIME: 1433

Depth (m)	Temp (C)	Cond. (mmhos/cm)	Salinity (°/oo)	Sigma T	D.O. (ppm)	Velocity (cm sec^{-1}/deg)	u (cm/sec)	v (cm/sec)
0*	28.1	17.4	9.6	3.5	11.7	25/216	-17	-19
2	26.7	17.2	9.8	4.0	6.8	25/183	-24	-6
4	26.7	17.2	9.8	4.0	6.3	28/164	-27	2
6	26.7	17.3	9.8	4.0	6.2	31/144	-28	12
8	26.7	17.8	10.1	4.2	5.7	28/134	-23	16
10	26.7	18.5	10.6	4.6	5.3	15/94	-4	15

Table 11.

PROFILE: 4B1 DATE: 8/22/78

STATION: B TIME: 1545

Depth (m)	Temp (C)	Cond. (mmhos/cm)	Salinity (°/oo)	Sigma T	D.O. (ppm)	Velocity (cm sec^{-1}/deg)	u (cm/sec)	v (cm/sec)
0*	28.0	17.5	9.7	3.5	11.6	13/301	9	-9
2	28.0	17.6	9.7	3.6	10.7	13/301	9	-9
4	28.0	17.9	9.9	3.7	8.3	21/340	21	-3
6	28.0	18.2	10.1	3.8	7.2	19/-4	18	2
8	28.0	18.2	10.1	3.8	7.1	15/4	15	4

Table 12.

PROFILE: 4B2 DATE: 8/22/78

STATION: B TIME: 1733

Depth (m)	Temp (C)	Cond. (mmhos/cm)	Salinity (°/oo)	Sigma T	D.O. (ppm)	Velocity (cm sec^{-1}/deg)	u (cm/sec)	v (cm/sec)
0*	28.9	17.4	9.4	3.1	10.5	21/315	18	-12
2	27.5	17.2	9.6	3.6	12.3	19/321	16	-9
4	27.5	17.1	9.6	3.6	9.5	22/337	21	-4
6	27.6	17.6	9.8	3.7	8.2	18/0	18	4
8	27.7	17.8	9.9	3.8	7.9	14/-12	14	0

* Surface current velocity readings were taken at 1-m depth to minimize surface-wave effects.

Vertical profiles of hydrographic variables in the Chesapeake Bay near Calvert Cliffs, Maryland.

Table 13.

PROFILE: 4B1 DATE: 8/22/78

STATION: C TIME: 1554

Depth (m)	Temp (C)	Cond. (mmhos/cm)	Salinity (^{o}/oo)	Sigma T	D.O. (ppm)	Velocity (cm sec^{-1}/deg)	u (cm/sec)	v (cm/sec)
0*	28.6	17.7	9.6	3.3	12.4	15/239	-5	-15
2	28.5	17.9	9.8	3.5	10.4	15/259	0	-15
4	28.4	18.0	9.9	3.5	10.1	10/302	7	-7
6	28.3	18.0	9.9	3.6	10.1	10/297	6	-7
8	28.3	18.0	9.9	3.6	10.0	10/307	7	-6
10	27.9	18.4	10.2	4.0	9.3	6/310	5	-4
12	26.7	21.9	12.7	6.2	3.4	7/77	0	7
14	25.6	26.1	15.7	8.7	0.4	13/311	10	-8

Table 14.

PROFILE: 4B2 DATE: 8/22/78

STATION: C TIME: 1744

Depth (m)	Temp (C)	Cond. (mmhos/cm)	Salinity (^{o}/oo)	Sigma T	D.O. (ppm)	Velocity (cm sec^{-1}/deg)	u (cm/sec)	v (cm/sec)
0*	28.8	17.8	9.7	3.3	13.7	13/281	5	-12
2	28.8	17.8	9.7	3.3	13.7	11/286	5	-10
4	28.4	17.9	9.8	3.5	13.5	6/290	3	-5
6	28.2	18.0	9.9	3.6	10.8	10/247	-2	-9
8	28.0	18.1	10.0	3.8	10.5	15/40	9	12
10	27.7	18.2	10.2	4.0	8.3	14/215	-10	-10
12	25.7	19.7	11.5	5.6	5.5	6/280	2	-6
14	25.5	25.3	15.5	8.6	0.3	19/2	19	5

* Surface current velocity readings were taken at 1-m depth to minimize surface-wave effects.

Table 15. Temperature data along Transect 1, Survey 4B, at six depths. Asterisks indicate data could not be collected.

PROJECT: CALVERT CLIFFS TRANSECTS
MAPPING: 4B
DATE: 082278
TIMES: 1445 TO 1543

*** TRANSECT 1 TEMPERATURE (C) DATA ***

READING NO.	0 M	0.5 M	1 M	3 M	5 M	7 M
1	28.3	28.3	28.0	27.1	26.8	26.8
2	28.3	28.3	28.0	27.0	26.8	26.8
3	28.3	28.3	28.0	27.0	26.8	26.8
4	28.3	28.3	28.1	27.0	26.8	26.8
5	28.3	28.3	28.1	27.0	26.8	26.8
6	28.3	28.3	28.0	27.0	26.8	26.8
7	28.3	28.3	28.1	27.0	26.7	26.8
8	28.3	28.3	28.1	26.9	26.8	26.8
9	28.3	28.3	28.1	26.9	26.7	26.8
10	28.3	28.3	28.1	26.9	26.7	26.8
11	28.3	28.3	28.1	26.8	26.8	26.8
12	28.4	28.3	28.0	26.8	26.8	26.8
13	28.4	28.3	28.1	26.8	26.8	26.8
14	28.4	28.3	28.1	26.8	26.7	26.8
15	28.3	28.3	28.1	26.8	26.8	26.8
16	28.3	28.3	28.1	26.8	26.7	26.2
17	28.4	28.3	28.1	26.8	26.7	26.8
18	28.4	28.3	28.1	26.8	26.8	26.8
19	28.4	28.3	28.2	26.9	26.7	26.8
20	28.4	28.4	28.2	26.9	26.7	26.8
21	28.4	28.4	28.3	26.8	26.7	26.8
22	28.5	28.4	28.1	26.8	26.7	26.8
23	28.4	28.4	28.1	26.8	26.7	26.8
24	28.5	28.4	28.2	26.8	26.7	26.8
25	28.5	28.4	28.1	26.8	26.7	26.8
26	28.5	28.4	28.3	26.8	26.7	26.8
27	28.5	28.4	28.1	26.8	26.7	26.8
28	28.4	28.3	28.1	*****	26.7	26.8
29	28.4	28.3	28.0	26.8	26.7	26.8
30	28.4	28.3	28.0	26.8	26.7	26.8
31	28.4	28.3	27.9	27.0	26.7	26.8
32	28.4	28.3	28.0	*****	26.7	26.6
33	28.4	28.3	28.0	*****	26.7	26.8
34	28.4	28.3	28.1	*****	26.7	26.8
35	28.5	28.3	27.7	*****	26.7	26.8
36	28.4	28.3	28.0	*****	26.7	26.8
37	28.4	28.3	28.0	*****	26.7	26.8
38	28.4	28.3	27.9	26.8	26.7	26.8
39	28.5	28.4	28.2	*****	26.7	26.8
40	28.5	28.4	28.1	*****	26.7	26.8
41	28.5	28.3	27.8	*****	26.7	26.9
42	28.5	28.4	28.1	*****	26.7	26.8
43	28.4	28.3	28.1	*****	26.7	26.8
44	28.5	28.3	28.1	27.6	26.7	26.6
45	28.5	28.4	28.1	*****	26.7	26.8
46	28.5	28.4	28.1	*****	26.8	26.8
47	28.6	28.4	28.2	*****	26.7	26.8
48	28.4	28.4	28.1	*****	26.7	26.8
49	28.5	28.3	28.0	*****	26.8	26.8
50	28.5	28.3	28.0	*****	26.7	26.8
51	28.5	28.4	28.1	*****	26.8	26.8
52	28.5	28.4	28.1	*****	26.8	26.8
53	28.5	28.4	28.1	*****	26.8	26.8
54	28.5	28.4	28.1	*****	26.8	26.8
55	28.5	28.4	28.2	*****	26.7	26.8
56	28.5	28.4	28.3	*****	26.8	26.8
57	28.5	28.3	28.1	*****	26.7	26.8
58	28.5	28.4	28.3	*****	26.8	26.8
59	28.5	28.4	28.2	*****	26.8	26.8
60	28.5	28.4	28.2	*****	26.7	26.8

Table 16. Temperature data along Transect 2, Survey 4B, at six depths. Asterisks indicate data could not be collected.

PROJECT: CALVERT CLIFFS TRANSECTS
MAPPING: 4B
DATE: 082278
TIMES: 1445 TO 1543

*** TRANSECT 2 TEMPERATURE (C) DATA ***

READING NO.	0 M	0.5 M	1 M	3 M	5 M	7 M
1	28.5	28.4	28.1	*****	26.8	26.8
2	28.5	28.4	28.2	*****	26.8	26.8
3	28.5	28.4	28.3	*****	26.8	26.8
4	28.5	28.4	28.2	*****	26.8	26.8
5	28.5	28.4	28.2	*****	26.8	26.8
6	28.5	28.3	28.1	*****	26.8	26.8
7	28.5	28.4	28.1	*****	26.8	26.8
8	28.5	28.3	28.2	*****	26.8	26.8
9	28.5	28.4	28.3	*****	26.8	26.8
10	28.5	28.4	28.3	27.1	26.8	26.8
11	28.5	28.4	28.3	*****	26.8	26.8
12	28.5	28.4	28.2	*****	26.9	26.8
13	28.5	28.4	28.3	*****	26.8	26.8
14	28.6	28.4	28.3	*****	26.7	26.8
15	28.6	28.4	28.3	*****	26.8	26.8
16	28.5	28.4	28.3	*****	26.8	26.8
17	28.6	28.5	28.1	*****	26.7	26.8
18	28.6	28.4	28.0	*****	26.6	26.7
19	28.7	28.5	28.3	*****	26.6	26.7
20	29.0	28.8	28.3	*****	26.6	26.7
21	29.0	28.8	28.1	*****	26.6	26.8
22	28.8	28.7	28.0	*****	26.7	26.8
23	28.8	28.5	28.2	*****	26.8	26.8
24	28.8	28.5	28.3	*****	26.8	26.8
25	28.8	28.6	28.3	*****	26.8	26.8
26	28.8	28.5	27.9	*****	26.8	26.8
27	28.8	28.6	28.4	*****	26.8	26.8
28	28.8	28.5	28.0	*****	27.0	27.0
29	28.6	28.5	27.5	27.3	27.2	*****
30	28.8	28.6	28.1	27.5	27.4	*****
31	28.5	28.3	28.0	27.6	27.2	*****
32	28.4	28.3	28.1	27.6	27.0	*****
33	28.3	28.3	28.1	27.5	26.9	*****
34	28.4	28.3	28.1	27.2	*****	*****
35	28.3	28.2	27.9	27.3	*****	*****
36	28.3	28.2	28.0	27.3	*****	*****
37	28.2	28.0	27.9	27.3	*****	*****
38	28.4	28.3	27.8	27.3	*****	*****
39	28.1	28.0	27.9	27.3	*****	*****
40	28.3	28.1	27.8	*****	*****	*****
41	28.1	28.0	27.8	*****	*****	*****
42	28.2	28.1	27.9	*****	*****	*****
43	28.3	28.1	27.9	*****	*****	*****

Table 17. Estimated dimensions of excess temperature isotherms for Mapping 4B, Chesapeake Bay near Calvert Cliffs, Maryland.

Mapping:	4B	Wind (m/sec):	2.1/NE
Date:	8/22/78	Air Temp. (°C):	25.9
Times:	1603-1727	Plant Load (MWe):	1540
Predicted Tidal Phase:	Flood	Intake Temp. (°C):	28.4
u (cm/sec)*:	15.9	Discharge Temp. (°C):	33.6
v (cm/sec)*:	-3.6		

Depth (m)	Estimated Ambient Temp. (°C)		Excess Isotherm (°C)	Estimated Enclosed Area ($x10^4$ m^2)§	Estimated Maximum Radial† Extent ($x10^3$ m)§
	Range	Mean			
0.0	28.3-28.8	28.5	4	0.4	0.1
			3	0.8	0.2
			2	5	0.7
			1	>100	>2.7
0.5	28.1-28.6	28.4	4	0.3	0.1
			3	0.8	0.2
			2	4	0.6
			1	>90	2.7
1.0	27.8-28.3	28.1	4	0.5	0.2
			3	1	0.2
			2	4	0.6
			1	>100	2.7
3.0	26.9-27.6	27.0	5	0.4	0.1
			4	0.8	0.2
			3	5	0.7
			2	>30	>1.5
5.0	26.7-27.0	26.7	5	0.3	0.1
			4	0.5	0.1
			3	4	0.8
			2	>30	2.2
			1	>100	>2.8
7.0	26.7-26.9	26.8	2	>2	0.0
			1	>80	>2.8

* Mean longitudinal component of current velocity u (positive upestuary), and mean lateral component, v (positive toward the eastern shore) derived from u and v measurements at Station B before and after the mappings.

§ Based on mean estimated ambient temperature.

† Measured from point of discharge.

Figures 8-13. Depictions of results of Mapping 4B at six depths in Chesapeake Bay near Calvert Cliffs, Maryland.

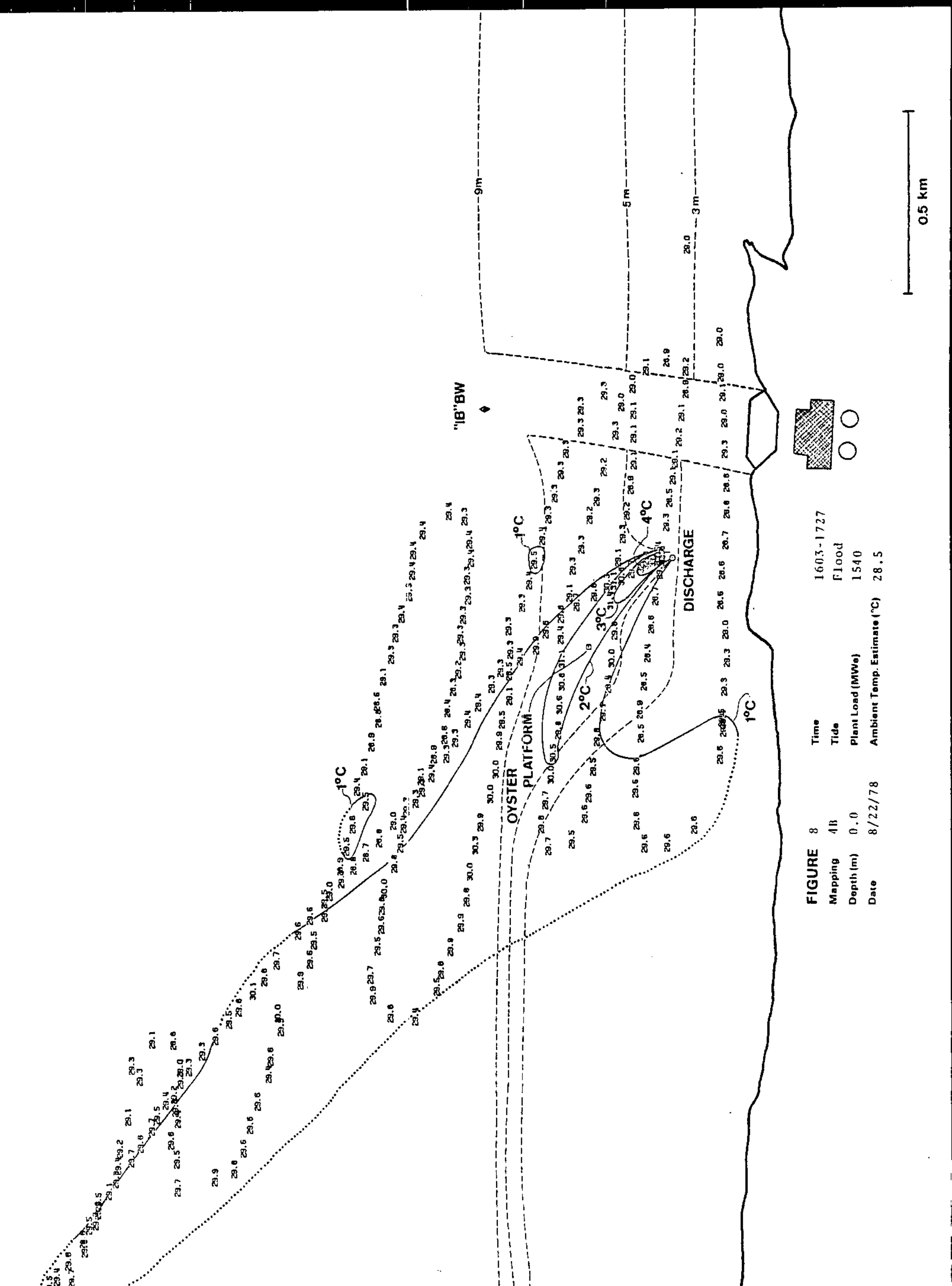

FIGURE 8

Mapping 4B	Time 1603-1727
Depth (m) 0.0	Tide Flood
Date 8/22/78	Plant Load (MWe) 1540
	Ambient Temp. Estimate (°C) 28.5

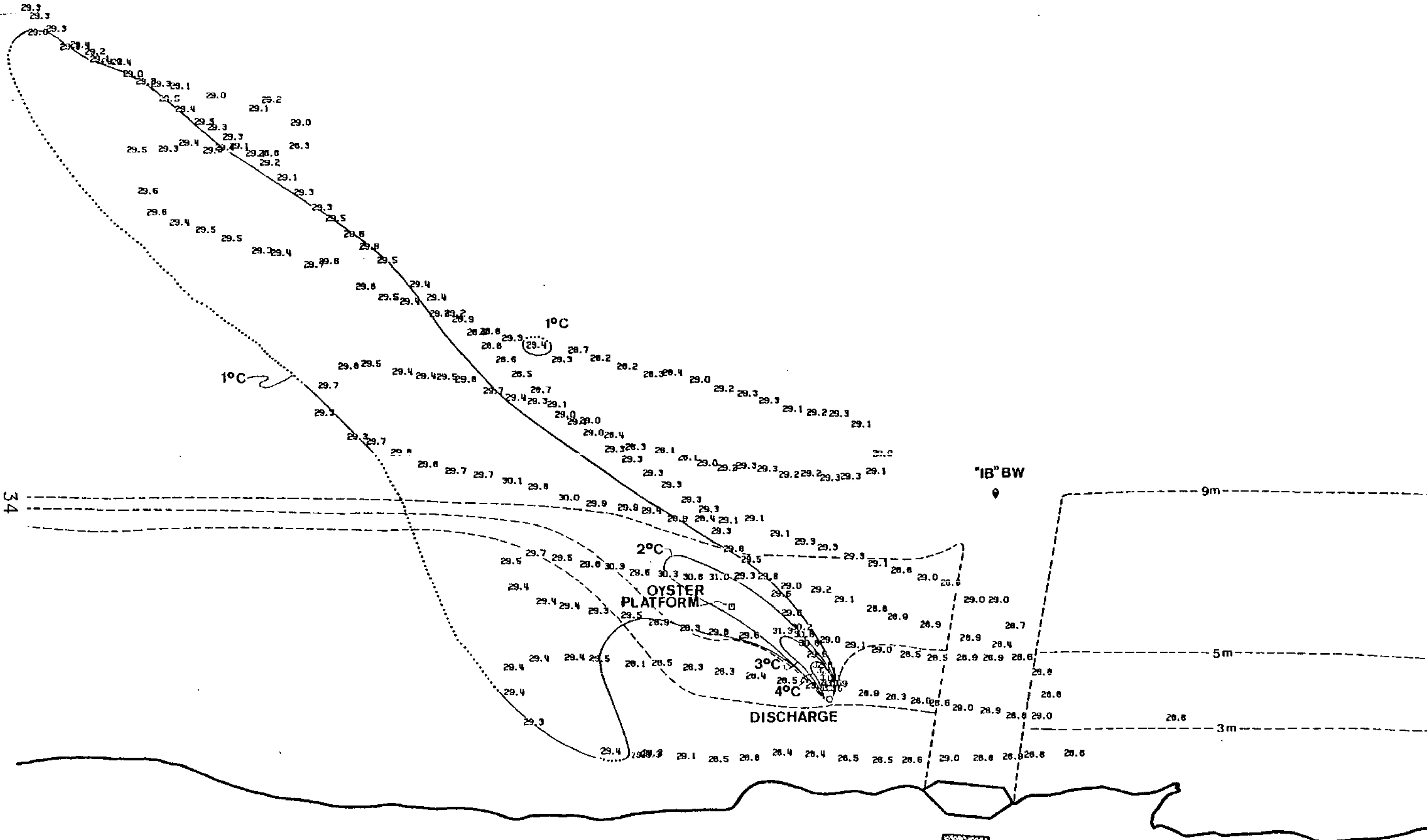

FIGURE	9	**Time**	1603-1727
Mapping	4B	**Tide**	Flood
Depth (m)	0.5	**Plant Load (MWe)**	1540
Date	8/22/78	**Ambient Temp. Estimate (°C)**	28.4

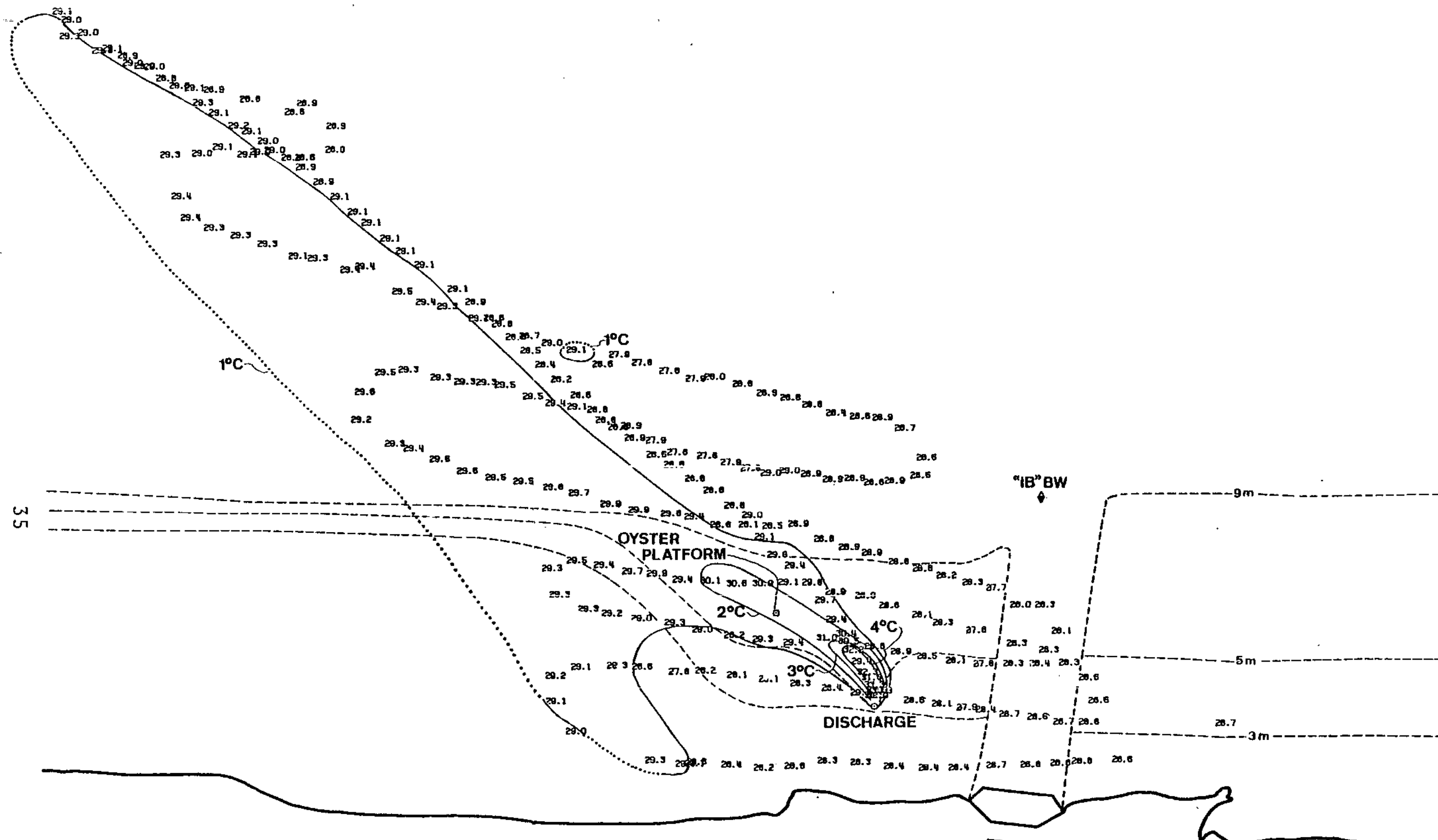

FIGURE	10	Time	1603-1727
Mapping	4B	Tide	Flood
Depth (m)	1.0	Plant Load (MWe)	1540
Date	8/22/78	Ambient Temp. Estimate (°C)	28.1

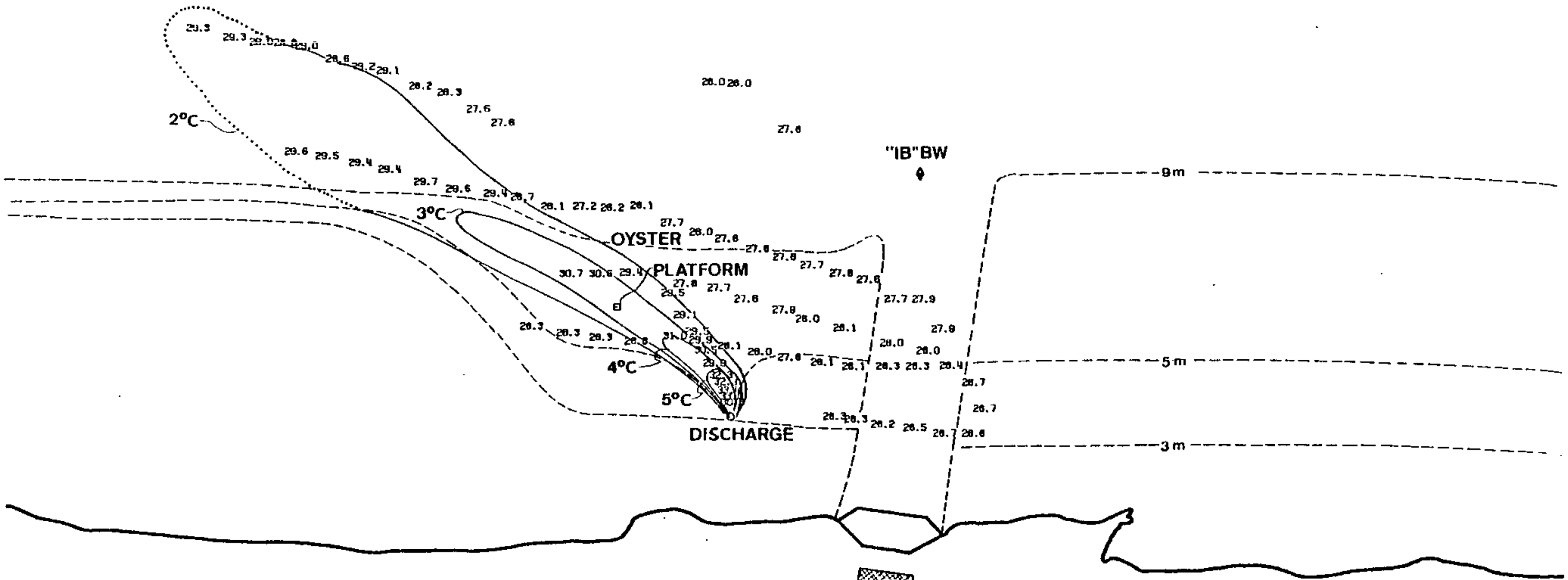

FIGURE	11*	**Time**	1603-1727
Mapping	4B	**Tide**	Flood
Depth (m)	3.0	**Plant Load (MWe)**	1540
Date	8/22/78	**Ambient Temp. Estimate (°C)**	27.0

* Mapping could not be completed because of thermistor failure.

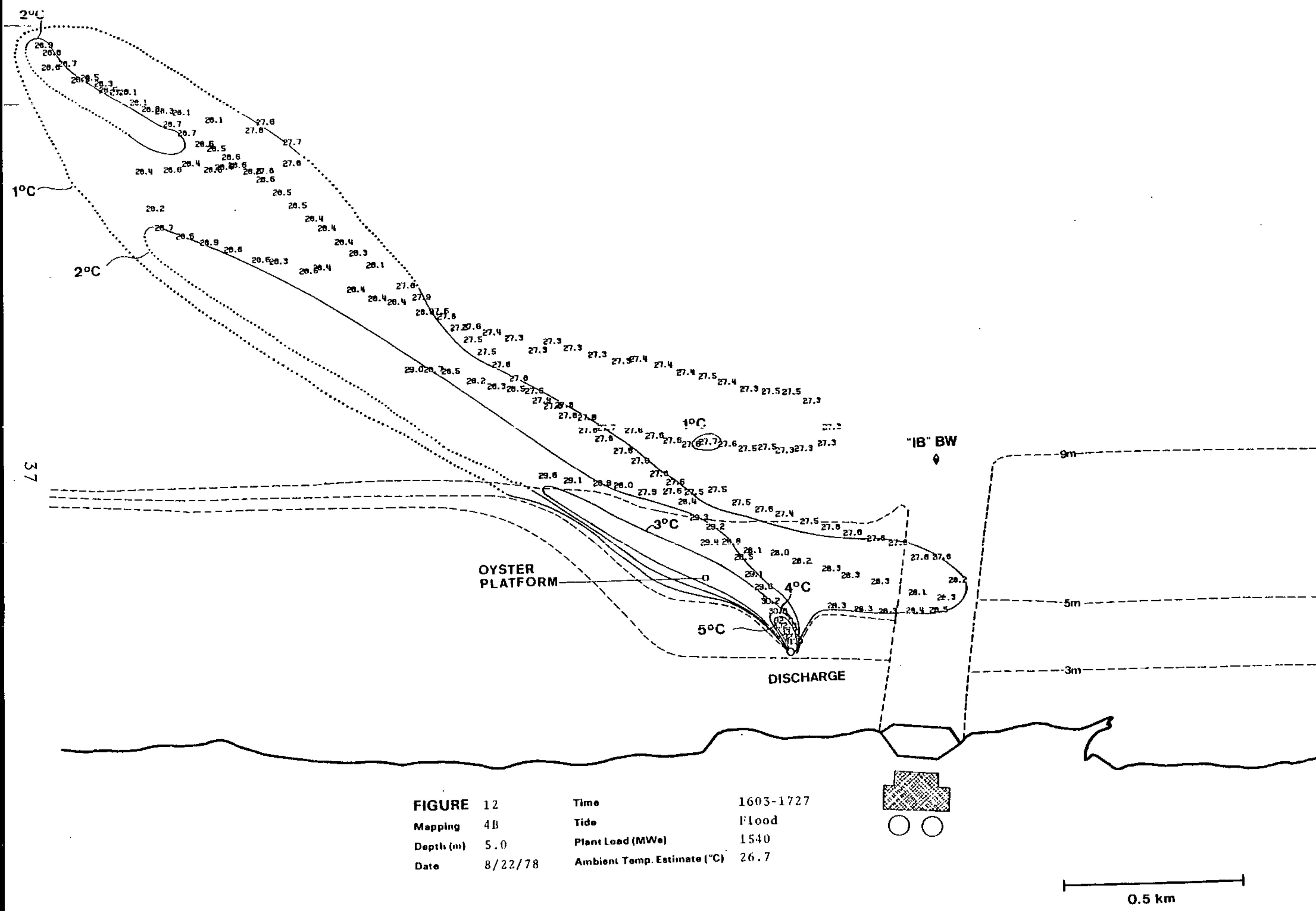

FIGURE	12	Time	1603-1727
Mapping	4B	Tide	Flood
Depth (m)	5.0	Plant Load (MWe)	1540
Date	8/22/78	Ambient Temp. Estimate (°C)	26.7

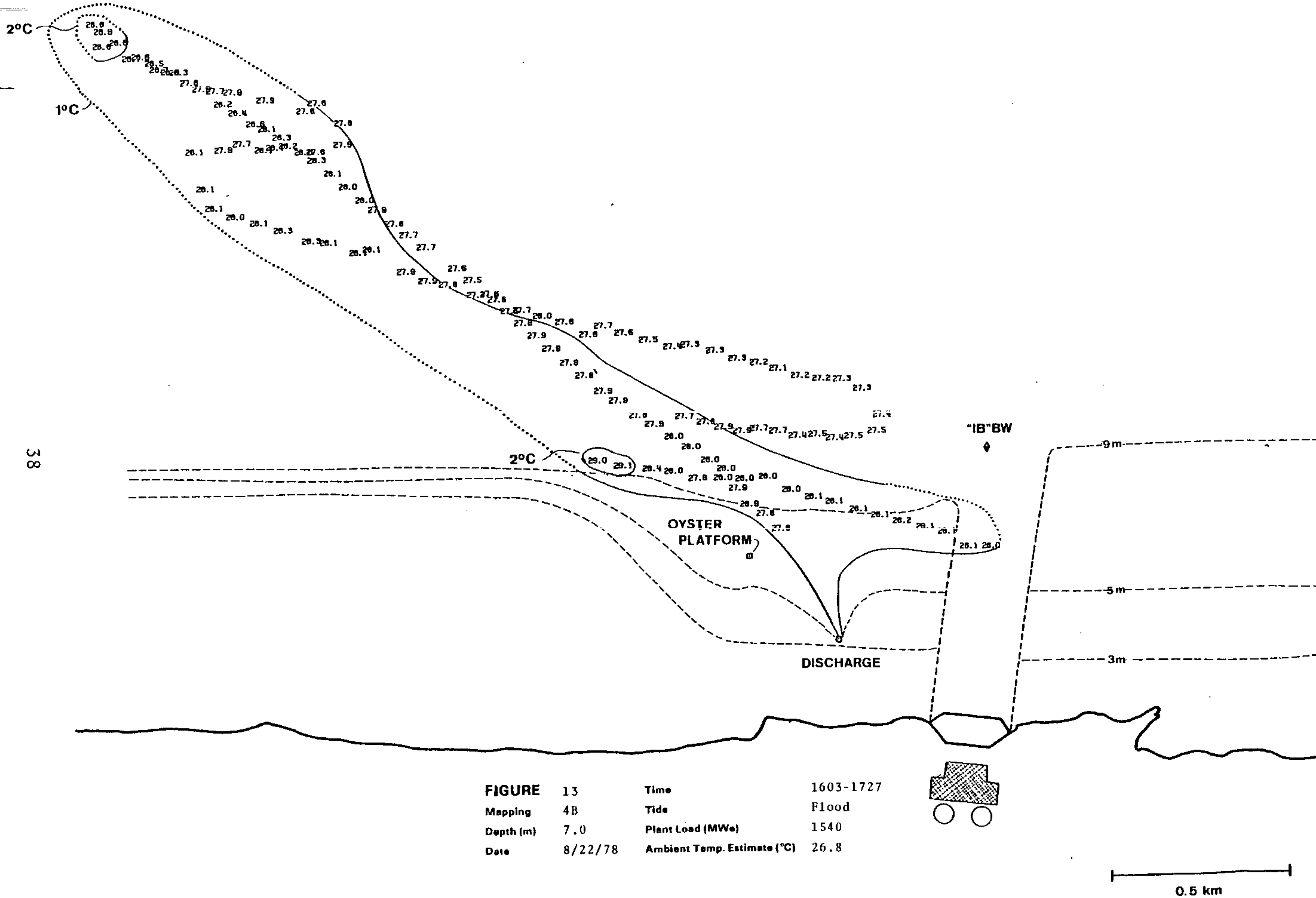

FIGURE	13	Time	1603-1727
Mapping	4B	Tide	Flood
Depth (m)	7.0	Plant Load (MWe)	1540
Date	8/22/78	Ambient Temp. Estimate (°C)	26.8

Vertical profiles of hydrographic variables in the Chesapeake Bay near Calvert Cliffs, Maryland.

Table 18.

PROFILE: 4C1

DATE: 8/23/78

STATION: A

TIME: 0754

Depth (m)	Temp (C)	Cond. (mmhos/cm)	Salinity (^{o}/oo)	Sigma T	D.O. (ppm)	Velocity (cm sec^{-1}/deg)	u (cm/sec)	v (cm/sec)
0*	26.9	17.2	9.7	3.9	7.9	10/12	9	4
2	26.9	17.2	9.7	3.9	7.9	15/344	15	-1
4	26.9	17.2	9.7	3.9	7.8	19/5	18	6
6	26.7	17.2	9.8	4.0	7.1	18/355	18	2
8	26.5	18.6	10.7	4.7	4.6	19/1	18	4
10	26.3	18.5	10.7	4.7	2.7	13/1	12	3

Table 19.

PROFILE: 4C1

DATE: 8/23/78

STATION: B

TIME: 0908

Depth (m)	Temp (C)	Cond. (mmhos/cm)	Salinity (^{o}/oo)	Sigma T	D.O. (ppm)	Velocity (cm sec^{-1}/deg)	u (cm/sec)	v (cm/sec)
0*	27.3	18.1	10.2	4.1	6.9	4/105	-2	4
2	27.1	18.2	10.3	4.2	6.8	9/75	1	9
4	27.1	18.0	10.2	4.1	6.8	10/172	-10	-1
6	27.1	18.0	10.2	4.1	6.8	13/161	-13	1
8	26.9	18.7	10.7	4.6	5.4	13/166	-13	0

Table 20.

PROFILE: 4C2

DATE: 8/23/78

STATION: B

TIME: 1053

Depth (m)	Temp (C)	Cond. (mmhos/cm)	Salinity (^{o}/oo)	Sigma T	D.O. (ppm)	Velocity (cm sec^{-1}/deg)	u (cm/sec)	v (cm/sec)
0*	28.4	18.9	10.4	3.9	6.5	15/59	5	15
2	28.5	18.9	10.4	3.9	6.4	15/65	3	15
4	27.9	18.9	10.5	4.2	6.2	19/65	4	18
6	27.5	19.0	10.7	4.4	5.4	18/85	-2	18
8	27.5	19.3	10.9	4.5	5.1	19/85	-2	18

* Surface current velocity readings were taken at 1-m depth to minimize surface-wave effects.

Vertical profiles of hydrographic variables in the Chesapeake Bay near Calvert Cliffs, Maryland.

Table 21.
PROFILE: 4C1 DATE: 8/23/78

STATION: C TIME: 0917

Depth (m)	Temp (C)	Cond. (mmhos/cm)	Salinity (^{o}/oo)	Sigma T	D.O. (ppm)	Velocity (cm sec^{-1}/deg)	u (cm/sec)	v (cm/sec)
0*	27.4	18.2	10.2	4.1	6.7	9/180	-9	-2
2	27.3	18.2	10.2	4.1	6.3	3/90	-1	3
4	27.3	18.3	10.3	4.2	5.8	3/355	3	0
6	27.1	18.6	10.5	4.4	5.5	21/278	7	-20
8	26.7	19.1	10.9	4.8	4.8	18/240	-6	-17
10	26.1	20.7	12.1	5.9	3.3	21/221	-13	-17
12	25.9	23.8	14.2	7.5	0.5	10/283	4	-9
14	25.9	24.6	14.7	7.9	0.2	4/120	-3	3

Table 22.
PROFILE: 4C2 DATE: 8/23/78

STATION: C TIME: 1103

Depth (m)	Temp (C)	Cond. (mmhos/cm)	Salinity (^{o}/oo)	Sigma T	D.O. (ppm)	Velocity (cm sec^{-1}/deg)	u (cm/sec)	v (cm/sec)
0*	28.1	18.6	10.3	3.9	7.3	15/135	-13	8
2	27.7	18.6	10.4	4.1	6.9	11/166	-11	0
4	27.3	18.5	10.4	4.3	7.1	10/227	-5	-8
6	27.1	18.5	10.5	4.4	6.3	9/270	2	-9
8	26.8	18.8	10.7	4.7	5.4	9/260	0	-9
10	26.5	20.8	12.0	5.7	3.2	15/261	1	-15
12	25.6	24.5	14.6	7.9	0.2	10/253	-1	-10
14	26.1	25.9	15.4	8.4	0.2	6/120	-4	4

* Surface current velocity readings were taken at 1-m depth to minimize surface-wave effects.